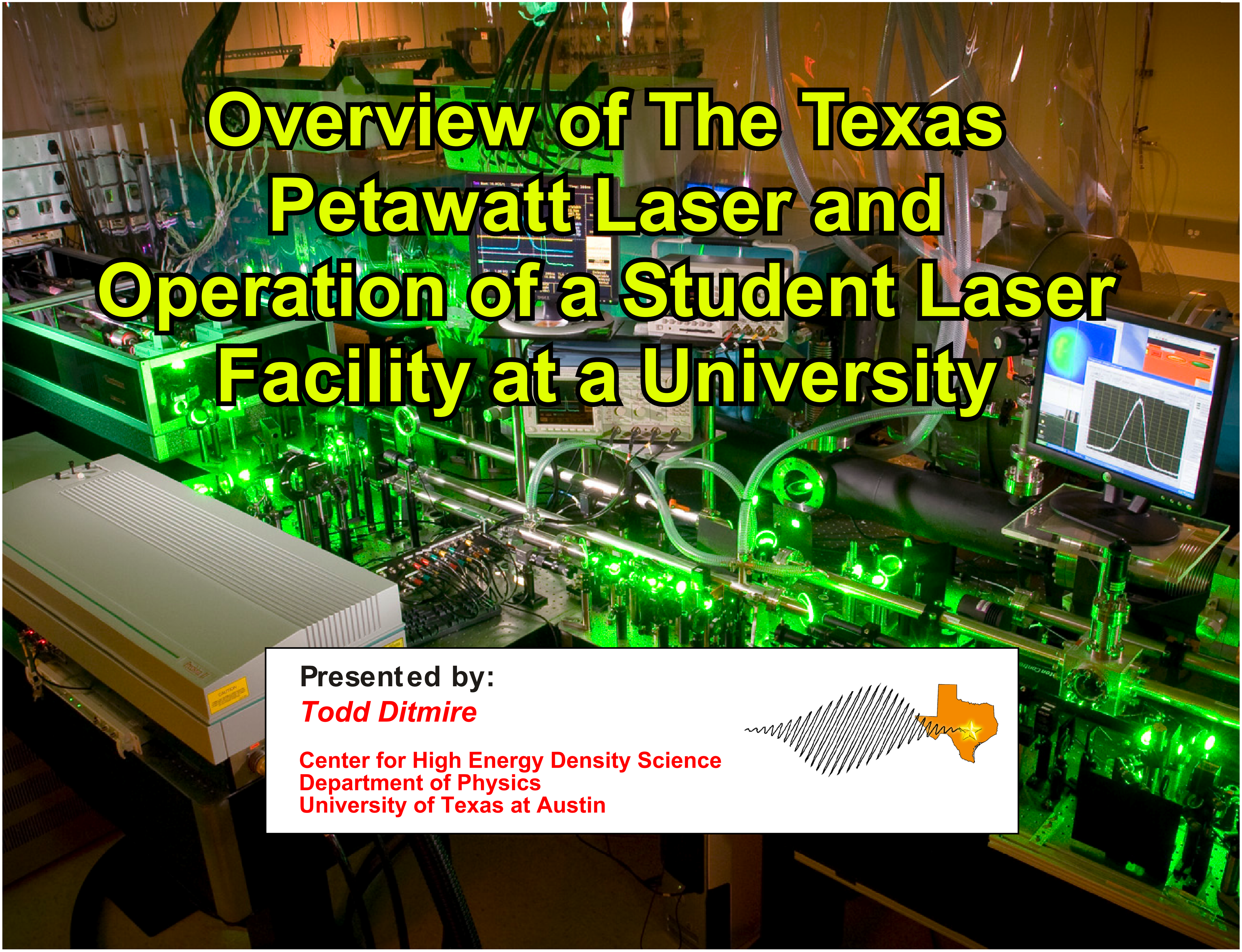


Overview of The Texas Petawatt Laser and Operation of a Student Laser Facility at a University

Presented by:

Todd Ditmire

Center for High Energy Density Science
Department of Physics
University of Texas at Austin

CHEDS is a center at the U. of Texas devoted to research in High Energy Density and High Intensity Laser physics

The Texas Center for High Intensity Laser Science (TCHILS) was established in July 2003 as an NNSA SSAA Center of Excellence under a cooperative agreement (DE-FC52-03NA00156). It was renewed for a further 5 years in 2008 (contract DE-FC52-08NA28512).

The Center was renamed CHEDS in 2010 when it became a College of Natural Sciences Organized Research Unit. The NNSA Cooperative agreement was renewed a second time in 2012 (contract DE-NA0002008)

Principal missions of CHEDS:

- Conduct research in laser driven HED science and shocked materials science and attract new students into these areas
- Train US citizen graduate students in these two areas
- Train students in how to plan and execute experiments on large scale HED facilities
- Develop novel and "high risk" HED diagnostics that could ultimately be fielded on the large HED facilities (NIF, Z and Omega)
- Collaborate on many experiments with National Laboratory scientists to remain coupled to the labs and to expose students to the activities of the labs
- Partner with the NNSA labs on technical projects and some facilities development
- Leverage existing efforts at UT in allied fields
    - Femtosecond Spectroscopy work (Downer et al.)
    - Magnetized plasma experiments (Bengtson et al.)
    - Large plasma physics theory Center, the Institute for Fusion Studies (Directed by F. Waelbroeck)

CHEDS includes ~ 50 faculty, scientists, post-docs, students, staff plus other collaborators

Center Faculty (5):
Roger Bengtson
Todd Ditmire
Mike Downer
Manuel Hegelich
John Keto

Center Senior Scientists (7):
Alex Arefiev
Aaron Bernstein
Michael Donovan
Gilliss Dyer
Erhard Gaul
Hernan Quevedo
Alan Wootton (IHEDS Director)

Closely Collaborating Scientists (11):
Alex Arefiev (IFS)
Stephan Bless (IAT)
Boris Breizman (IFS)
Charles Chiu
Robert Wyatt (Chemistry)
Jung-Fu Lin (Geological Sciences)
Aaron Edens (Sandia)
Richard Fitzpatrick (IFS)
Wendell Horton (IFS)
Jens Osterholz (Dusseldorf)
Gennady Shevts (IFS)

Graduate Students (16):
Joel Blakeney
Sandra Bruce
Lingyuan Gao
Sean Grant
Ahmed Helal
In Tai Kim
Donghoon Kuk
Sean Lewis
Edward McCary
Matthew McCormick
Alexander Meadows
Nathan Riley
Rebecca Roycroft
Kristina Serratto
Craig Wagner
Matt Wisher

Post-Docs (2):
Ishay Pomerantz
Chunhua Wang

Undergraduate Students (14):
Vishal Bhatnagar
Andrew Brooks
Clay Chester
Jose Cortez
David Hamilton
Jacob Jordan
Lilly Kim
Andrew Lafferty
Vincent Minello
Kevin Nguyen
Esgar Rodriguez
Brandon Simon
Jessica Sosa
Alex Wilhelm

Technical Staff (4):
Technical Staff Associate (position formerly held by Ted Borger)
Michael Spinks
Mikael Martinez
Martin Ringuette

Administrative Staff (4):
Sharee Aery
Maria Aguirre
2 work study students

The Center of High Energy Density Science (CHEDS) is organized with three core entities

Center for High Energy Density Science (CHEDS)

Director: Todd Ditmire
ORU Faculty:
Roger Bengtson
Mike Downer
Manuel Hegelich
John Keto
(Eric Taleff, ME)

TCHILS
(Texas Center for High Intensity Laser Science)

Aaron Bernstein
Associate Director for TCHILS
Funding: DOE NNSA

Purview:
Student research on high intensity laser experiment, using UT and other NNSA laser facilities

TPW
(Texas Petawatt Facility)

Mike Donovan
Facility Director for TPW
Funding: UT Office of the Provost

Purview:
Safe and efficient operation of the Texas Petawatt laser as a user facility for Internal and external use

IHEDS
(UT/Sandia Joint Institute for High Energy Density Science)

Alan Wootton
Associate Director for IHEDS
Funding: UT System; Sandia; DOE SC

Purview:
Facilitation of UT and other academics as users on Sandia's large HED machines

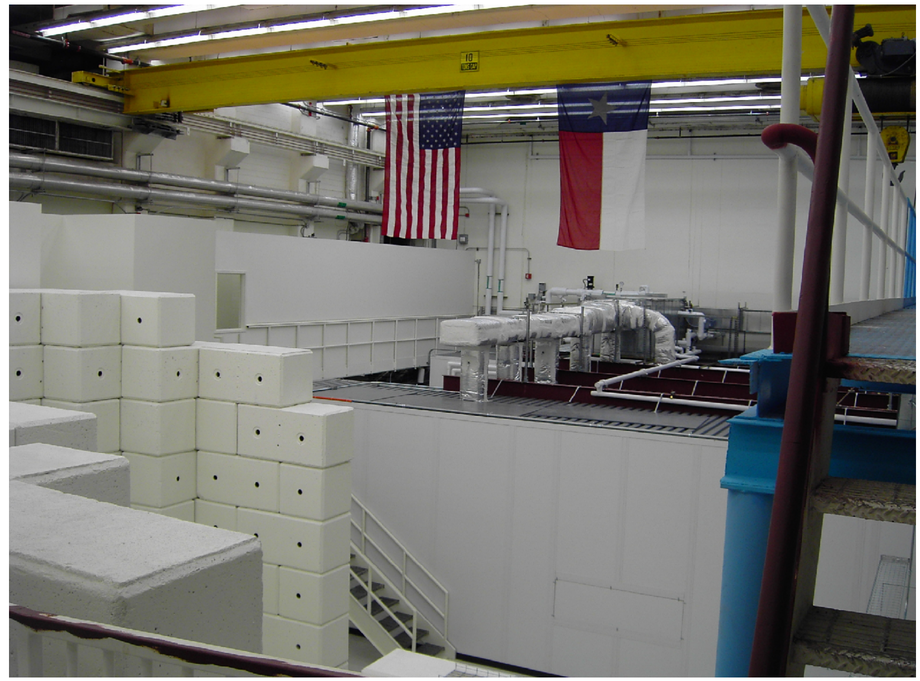
We maintain a number of active collaborations including many with NNSA labs

Institutions with which CHEDS has active collaboration in the past five years

1) Sandia National Laboratories
2) Lawrence Livermore National Laboratory
3) Los Alamos National Laboratory
4) Ohio State University
5) University of Nevada, Reno
6) Rice University
7) TU Berlin, Uppsala University, OSU - LCLS collaboration
8) Harvey Mudd College
9) Lockheed Martin Missiles and Fire Control Division
10) Cyclotron Center, Texas A&M University
11) Max Planck Institute for Complex Systems, Dresden
12) Hebrew University, Israel
13) U. of Chicago
14) LMU, Munich
15) UC San Diego
16) Rutherford Appleton Lab, UK
17) U. of York
18) NSTec

The Texas Petawatt Laser, sited centrally on the UT campus, is the centerpiece of the CHEDS science effort

The Robert Lee Moore Hall

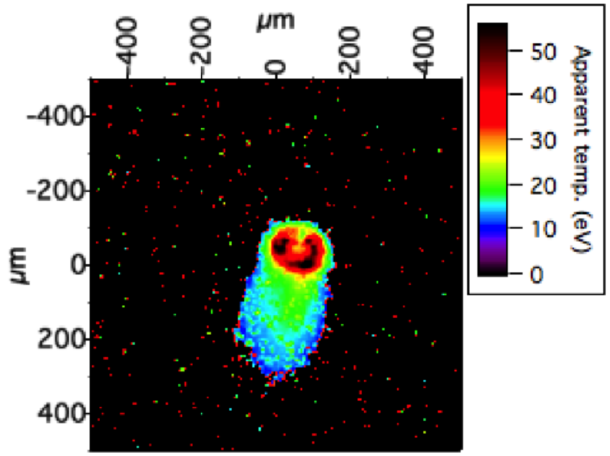


Laboratory high bay beneath the plaza in front of RLM

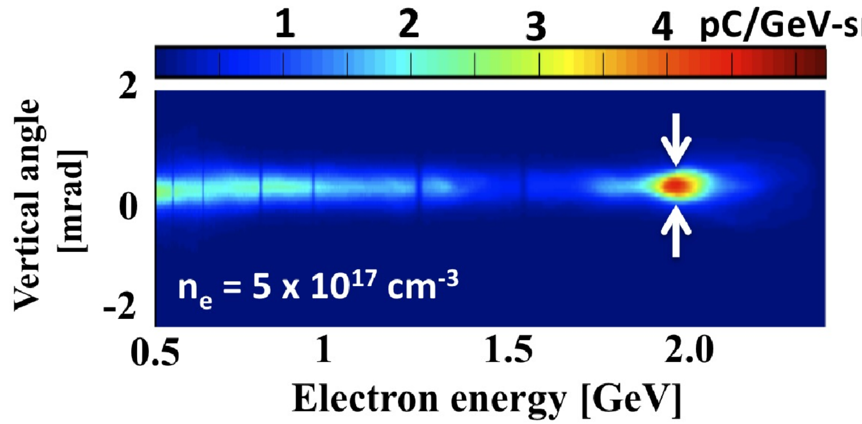
The Texas Petawatt Laser is housed underground in the Physics Department building. It is open to students and post doctoral researchers of a wide range of experiences

CHEDS conducts research in four principal thrust areas

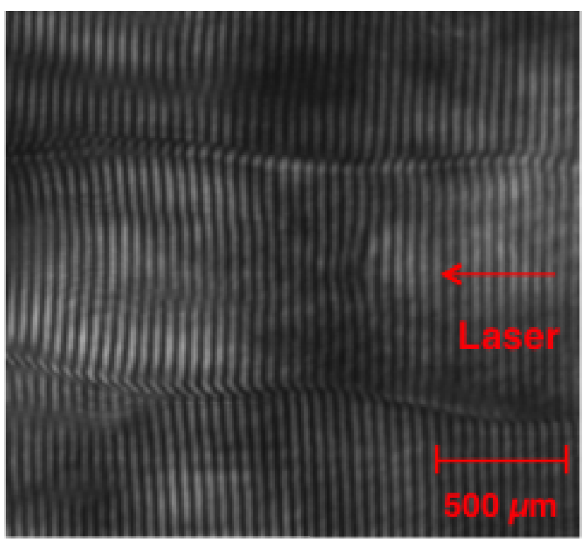
1) Properties of Warm and Hot Dense Plasma



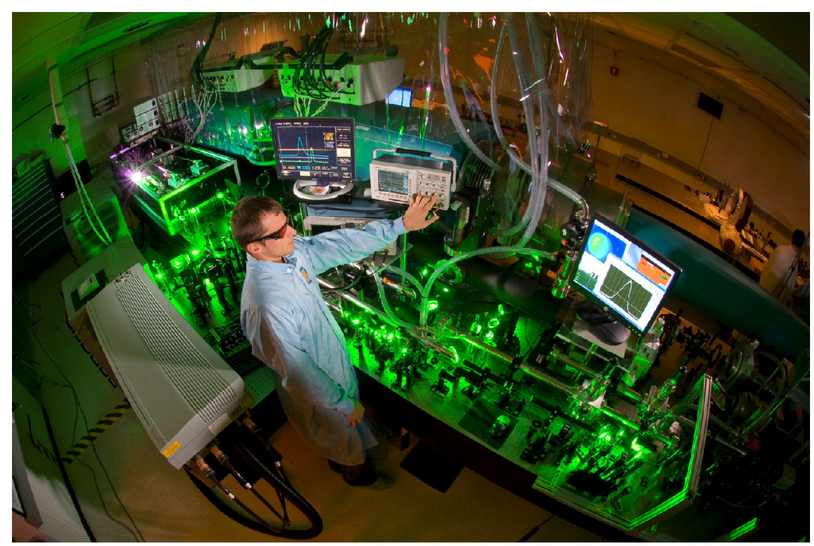
2) High Energy Particle and Radiation Production



3) Shock and Blast Wave Physics



4) High Peak Power Ultrafast Laser Technology

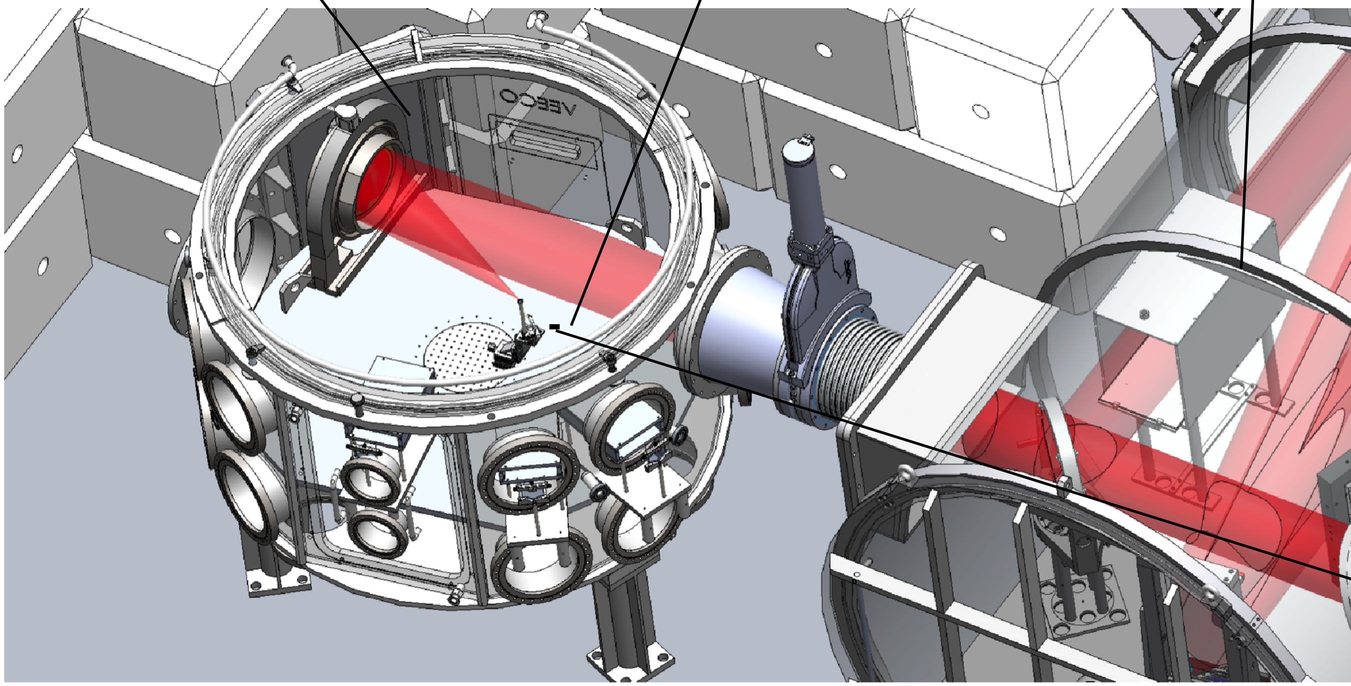


We have undertaken a campaign to characterize proton acceleration with 100 fs petawatt pulses

f/3 focusing parabola

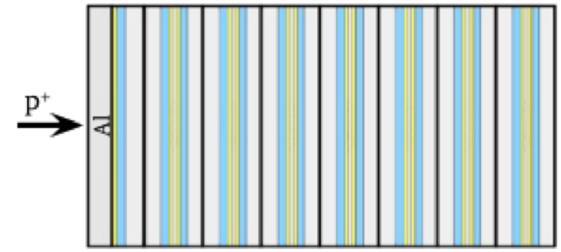
1 - 25 μm thick foil target

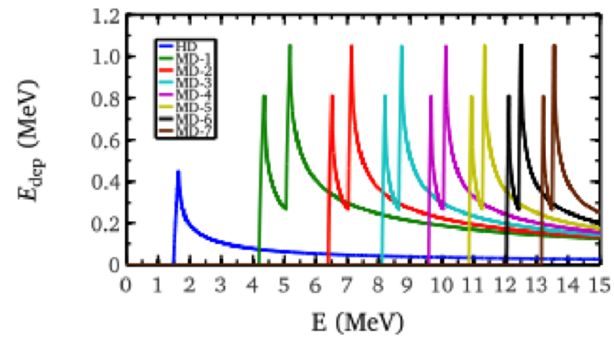
Vacuum pulse compressor chamber

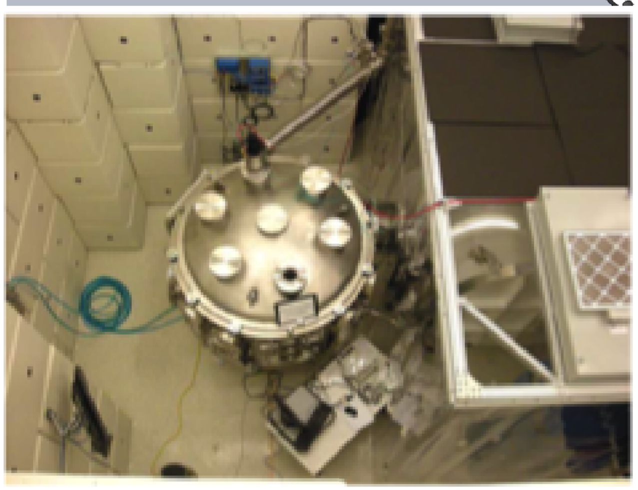


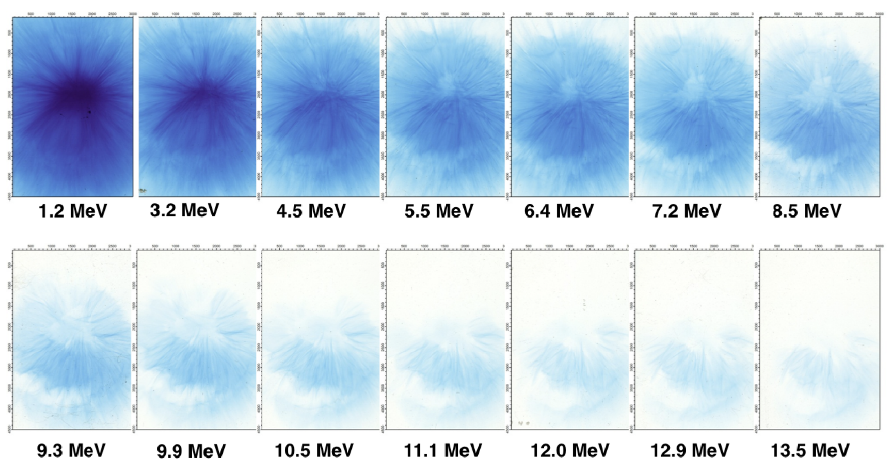
Radiochromic film stack

RCF Diagnostic

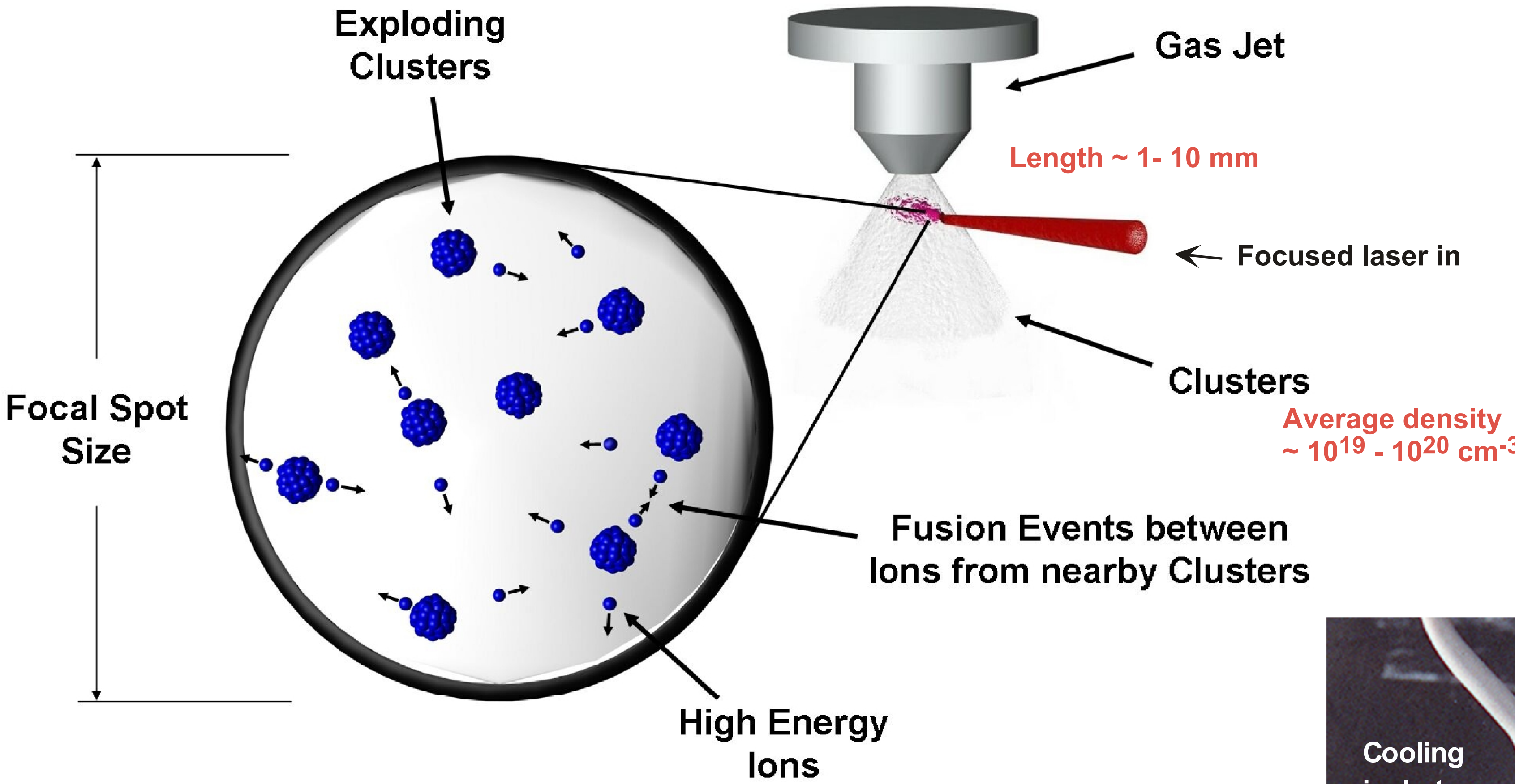








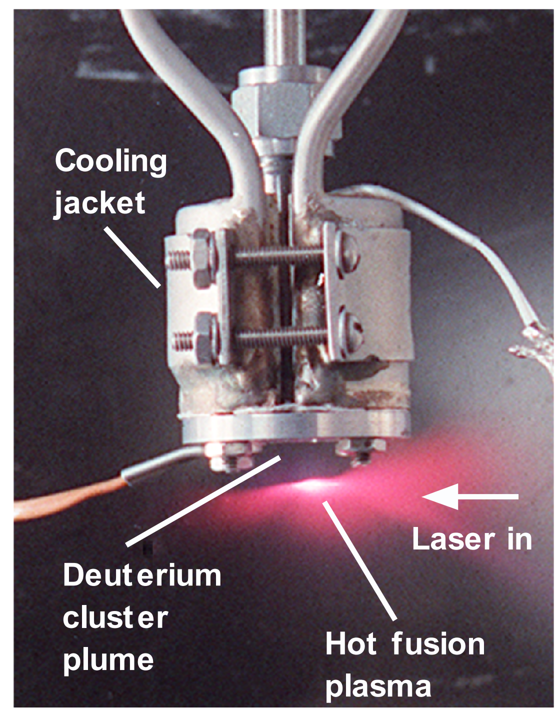
A gas of exploding deuterated clusters can produce a burst of fusion



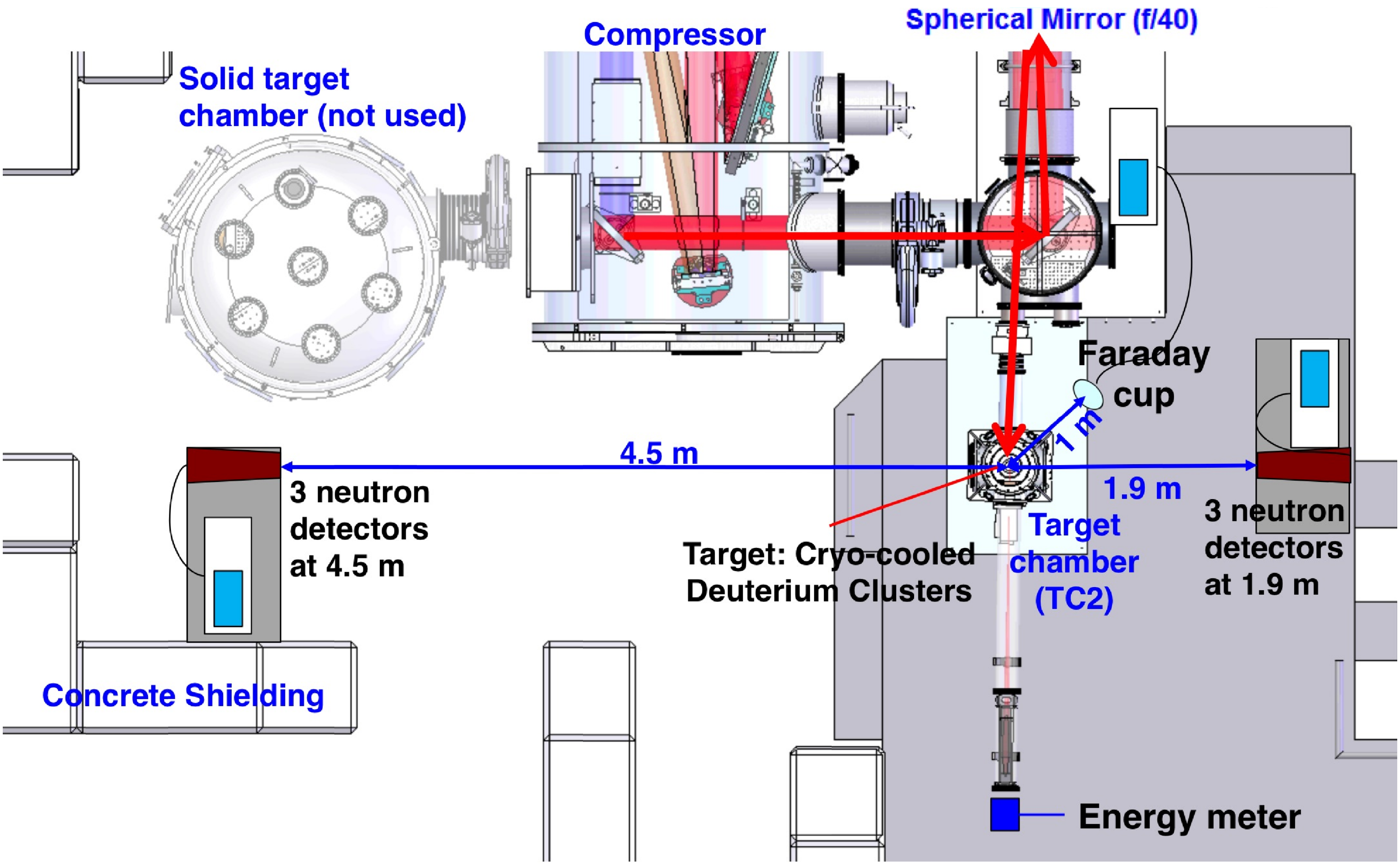
Relevant fusion reactions:

D + D $\rightarrow$ He^3 (0.82 MeV) + n (2.45 MeV)

D + T $\rightarrow$ He^4 (3.5 MeV) + n (14.1 MeV)

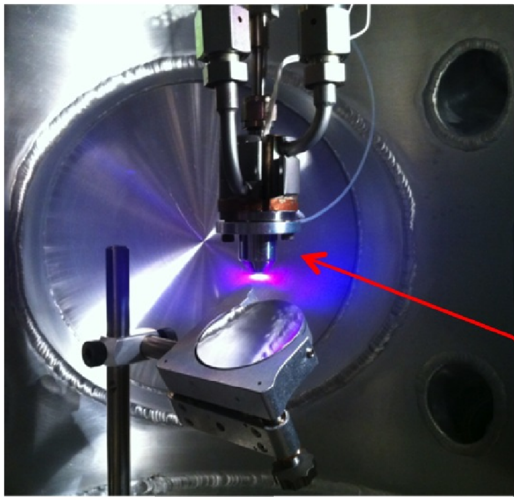


A series of DD cluster fusion experiments have been performed on the Texas Petawatt Laser

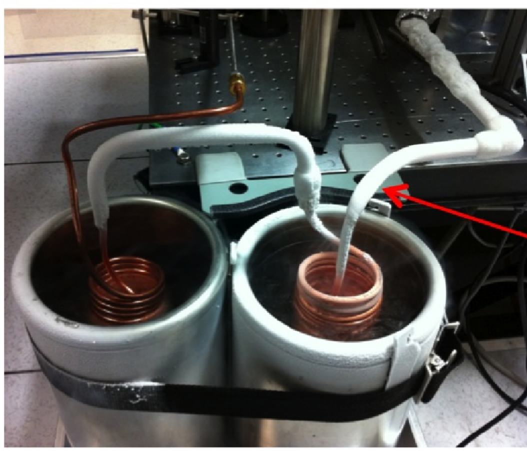


We have produced ~ 2 x 10^7 DD fusion n/shot in clusters with the Texas Petawatt Laser (~ 150 J energy)

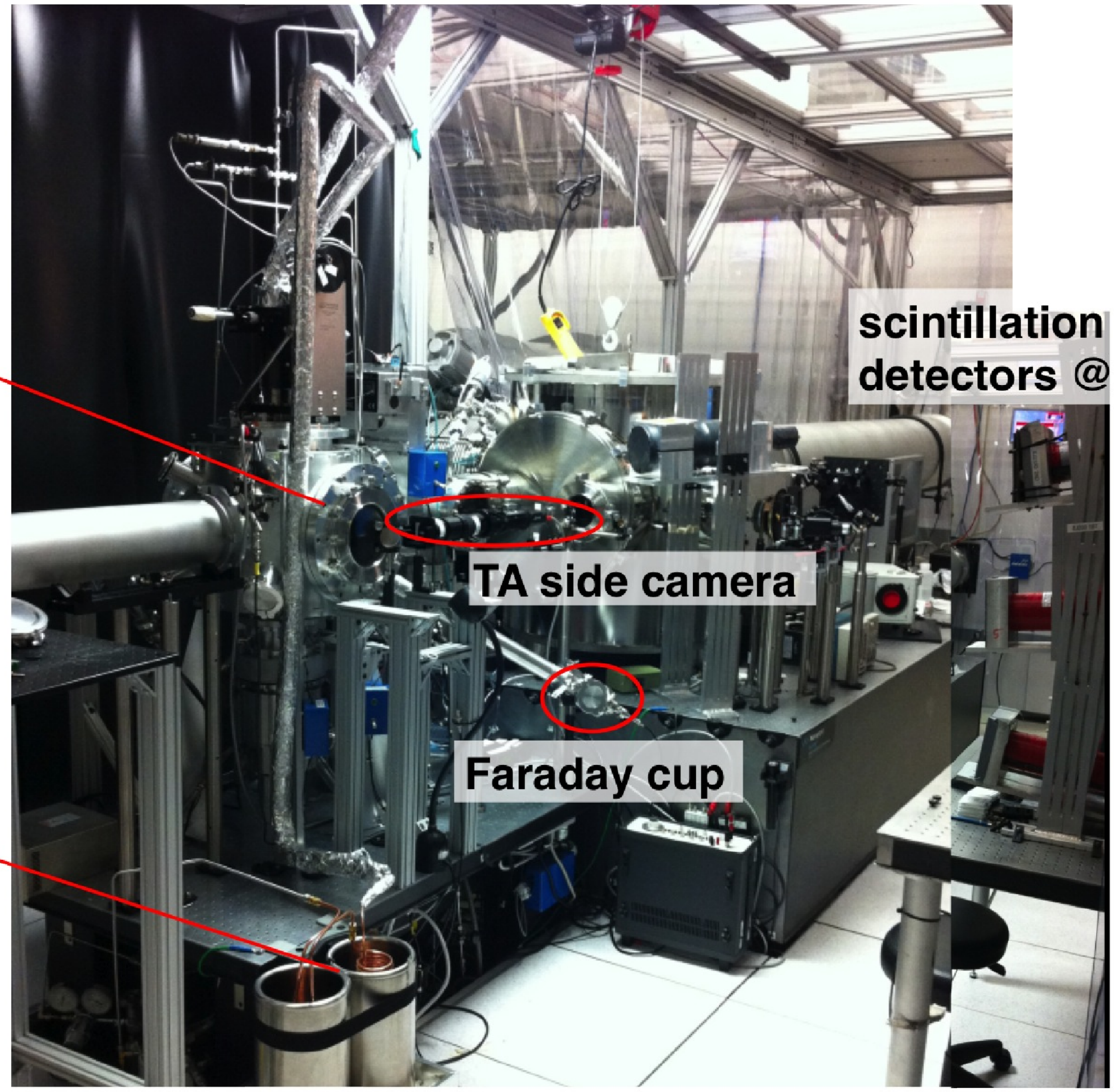
Target area of the TPW for the cluster fusion experiment



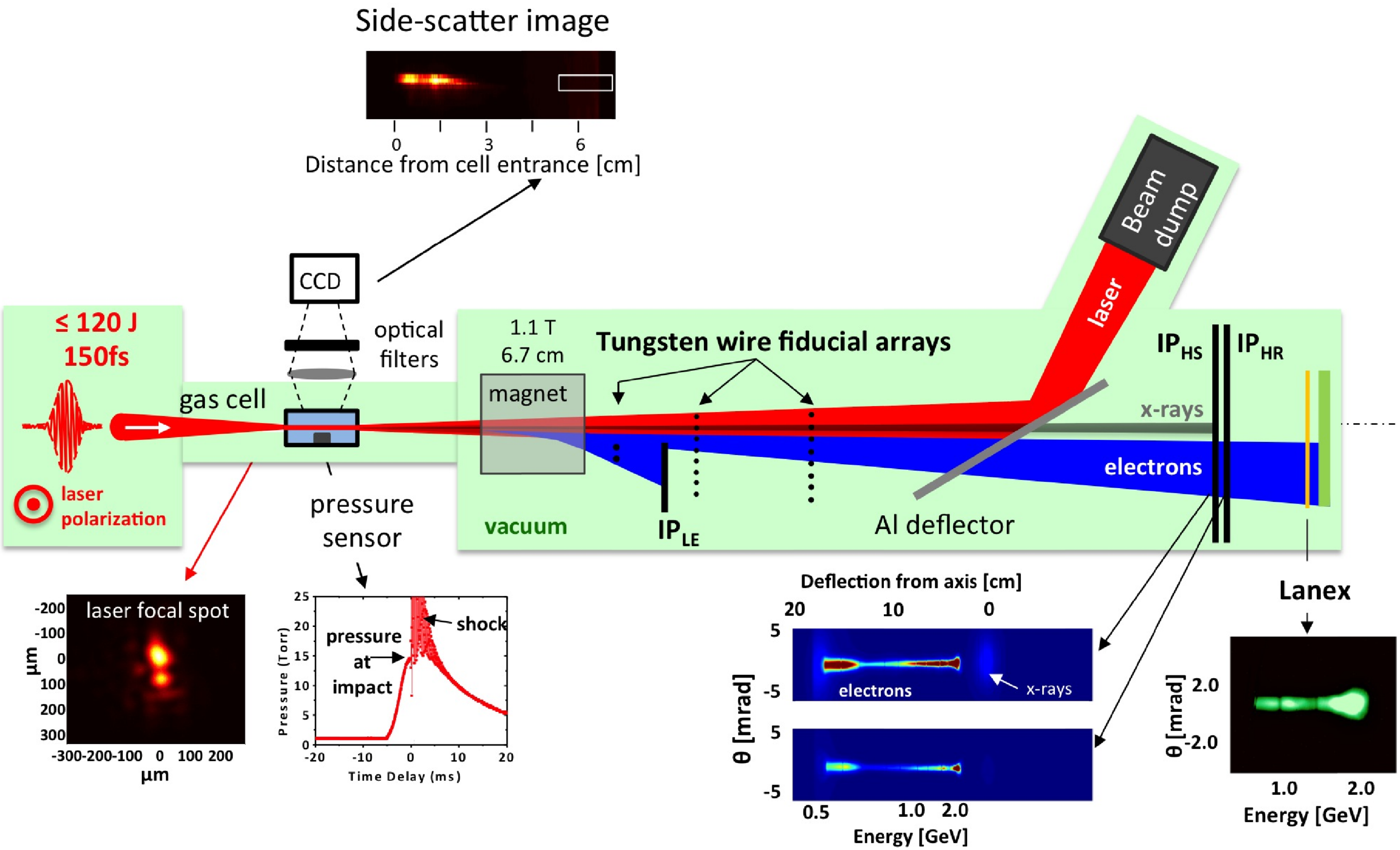
Deuterium plasma filament



LN2 cooling line

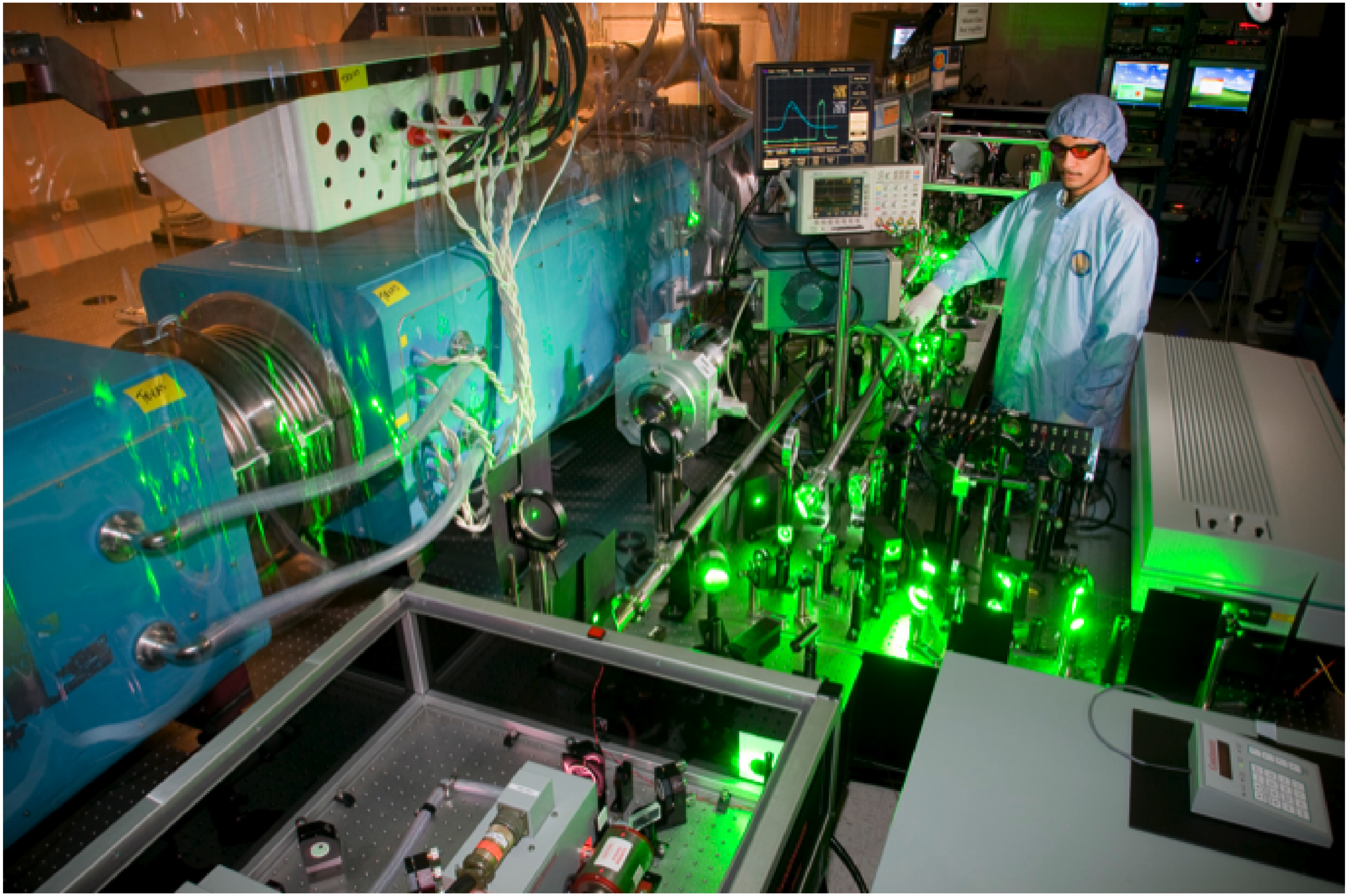


Multi-GeV electrons are produced in wakefield acceleration experiments

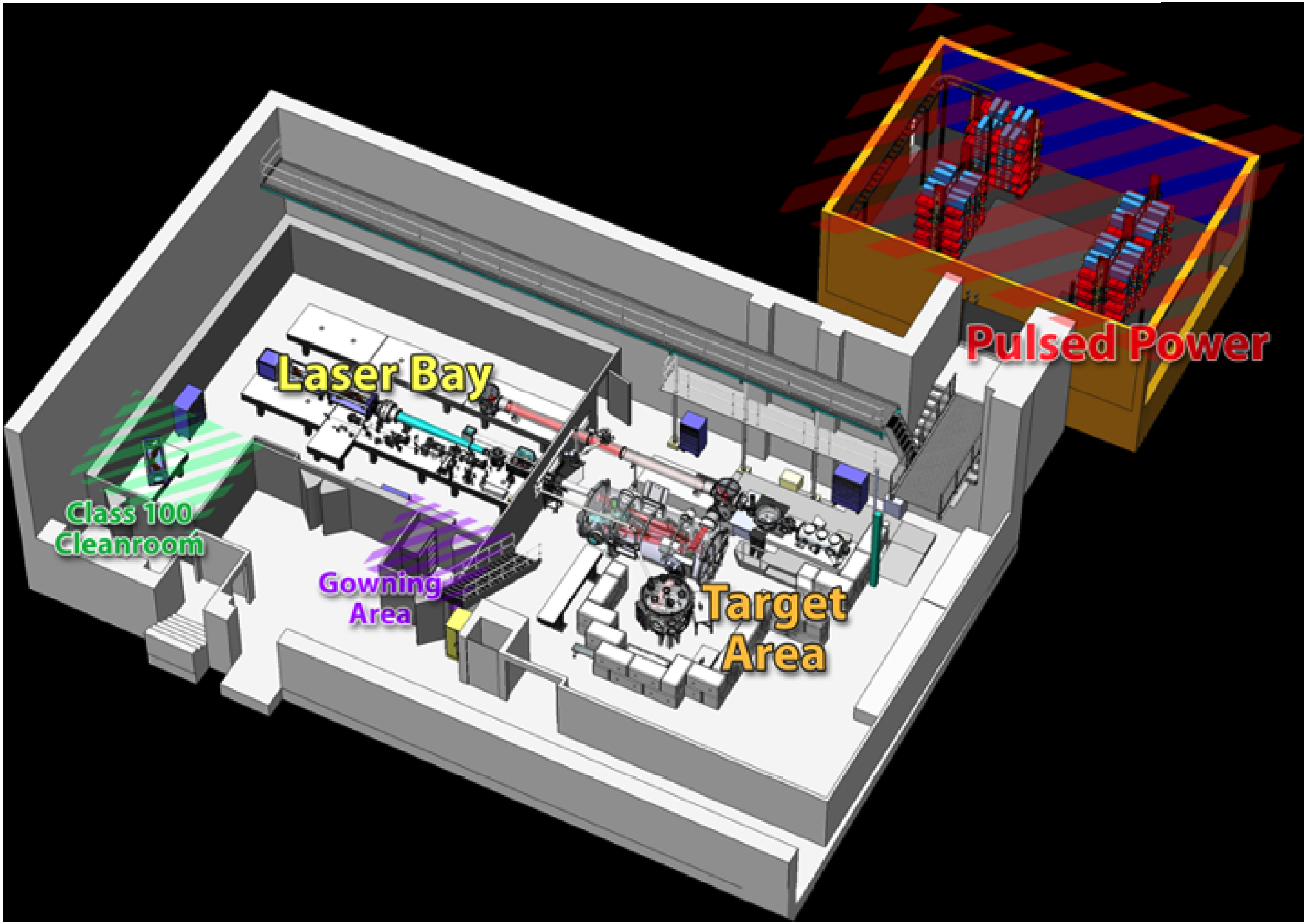



High Peak Power Ultrafast Laser Technology:
The Texas Petawatt Laser Facility

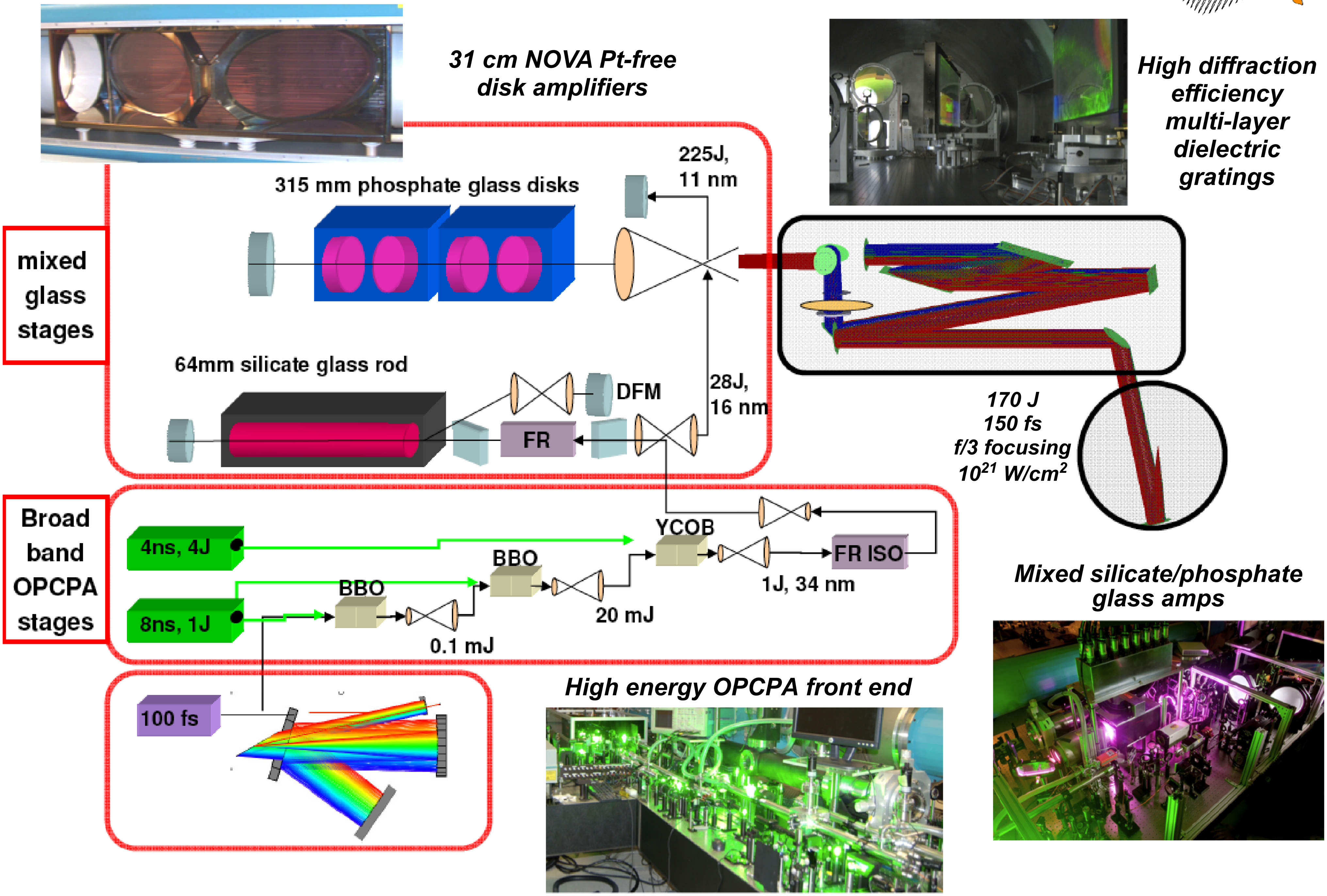
The Texas Petawatt is a 150 fs laser delivering up to 170J of energy to target



The TPW Laser is housed underground in the UT Austin Robert Lee Moore high bay

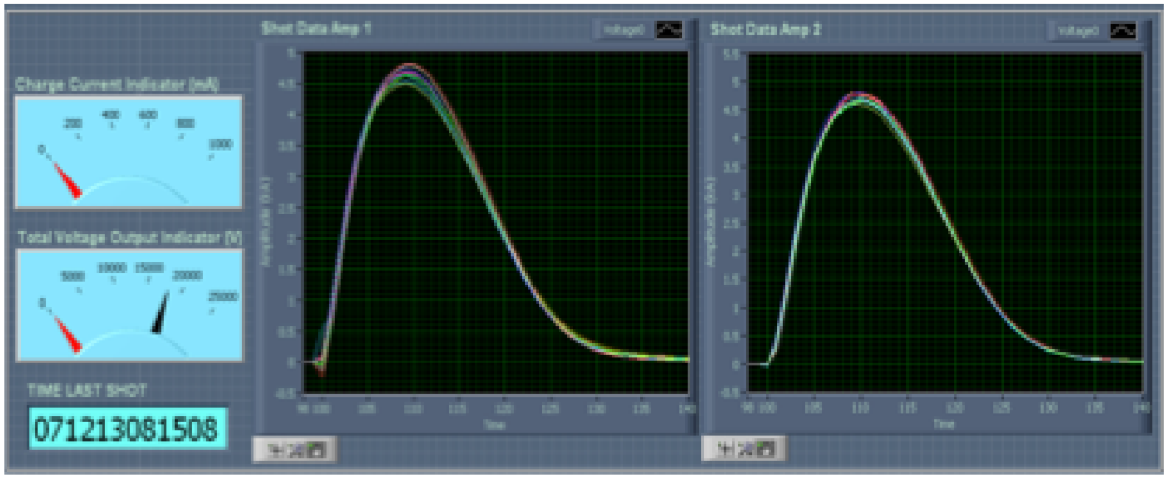


The Texas Petawatt design is based on a 3-stage OPCPA amp and a mixed glass chain

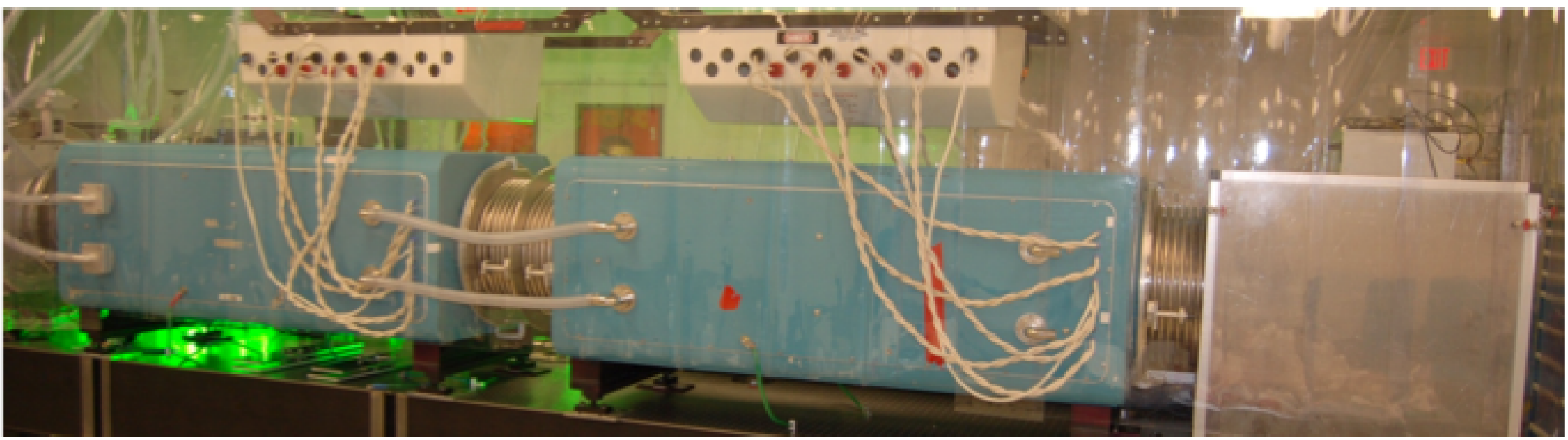


Two NOVA 31 cm disk amplifiers employing phosphate Nd:glass provide final amplification to >200 J

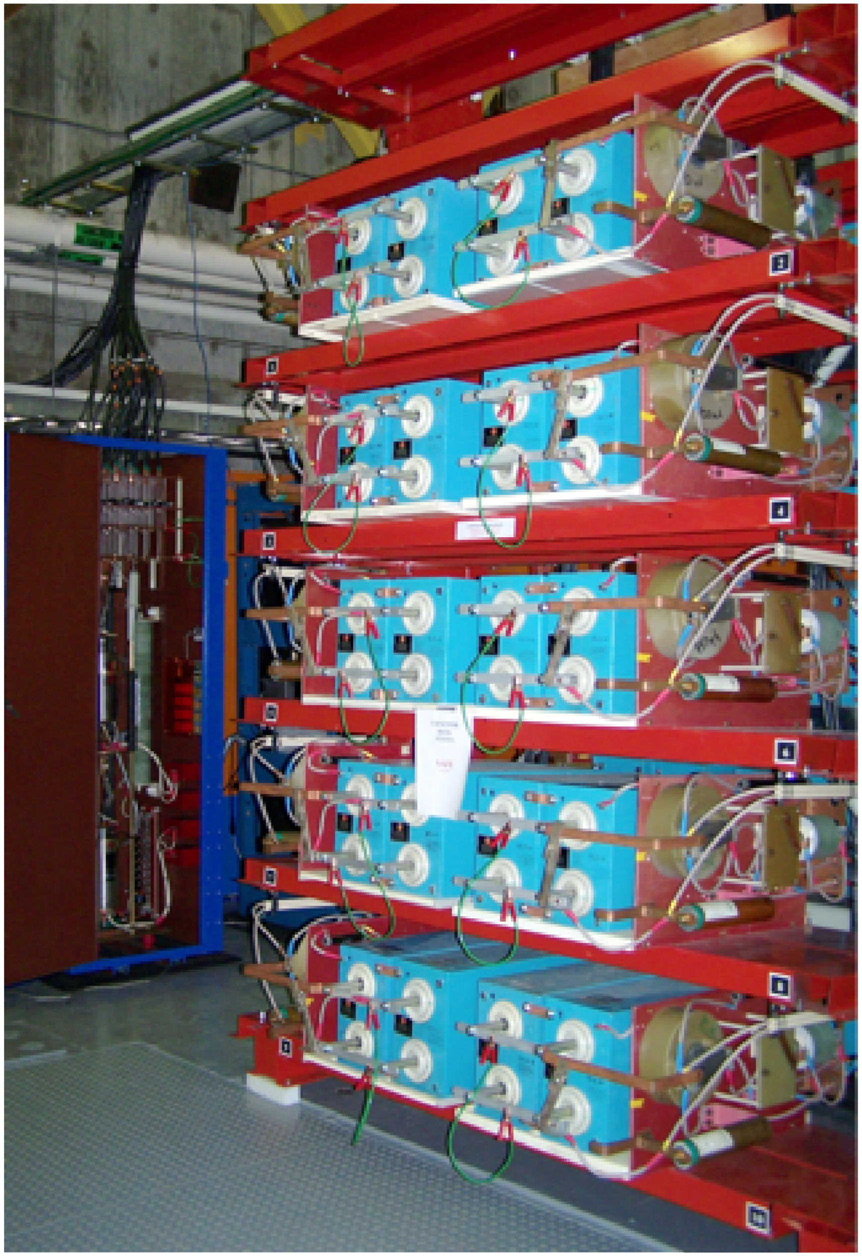
- up to 248 J achieved, with 80% charge voltage
- Energy limited by gratings, not by gain.
- Labview control for system shots and diagnostic



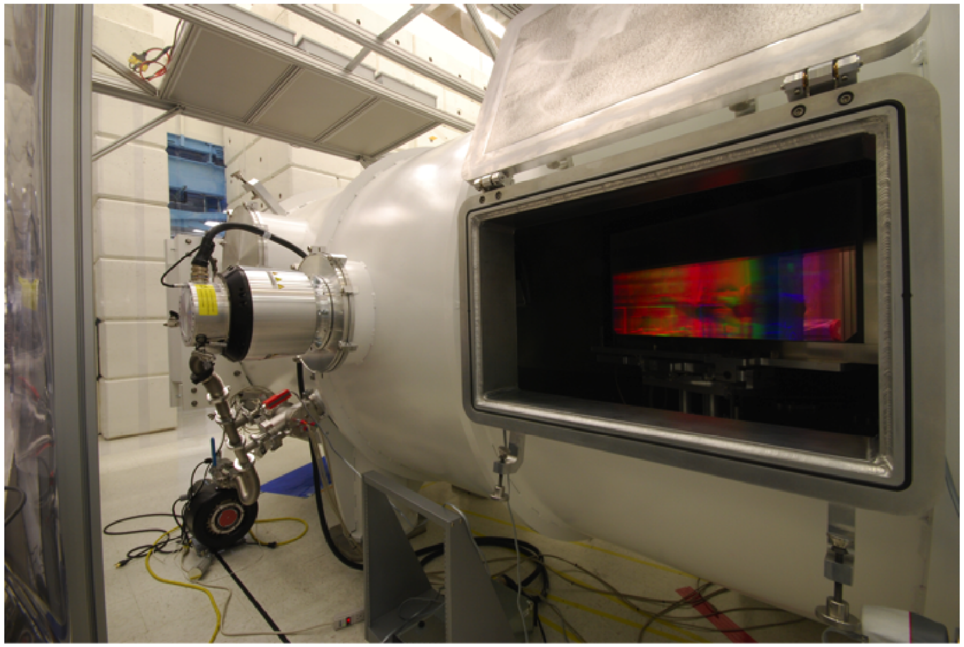
315 mm Phosphate Nd:glass disk

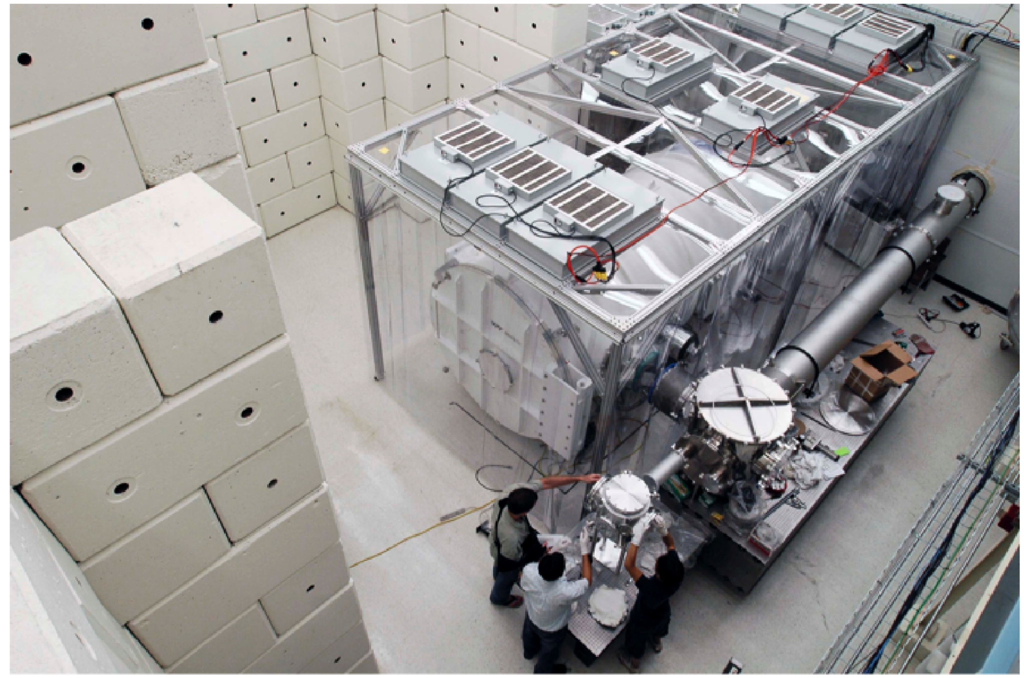


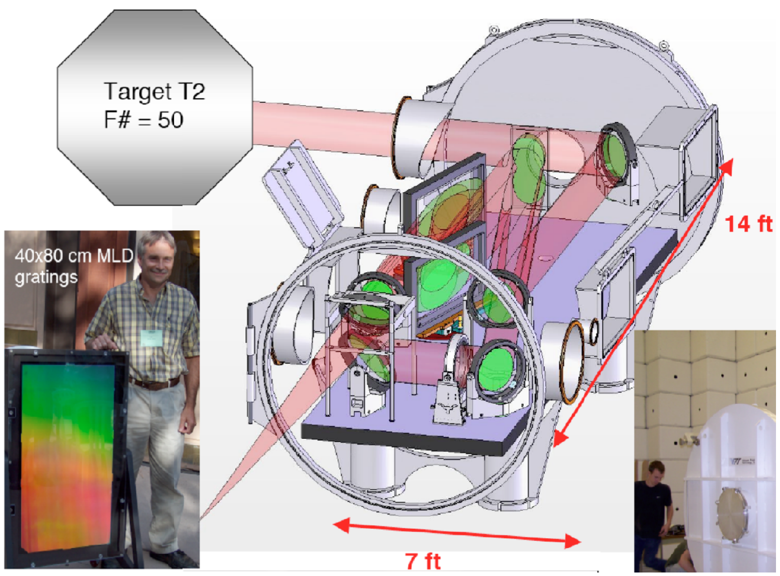
The 31 cm disk amplifiers are driven by a 0.5 MJ pulsed power rack



The MLD gratings in the TPW perform well with high diffraction efficiency

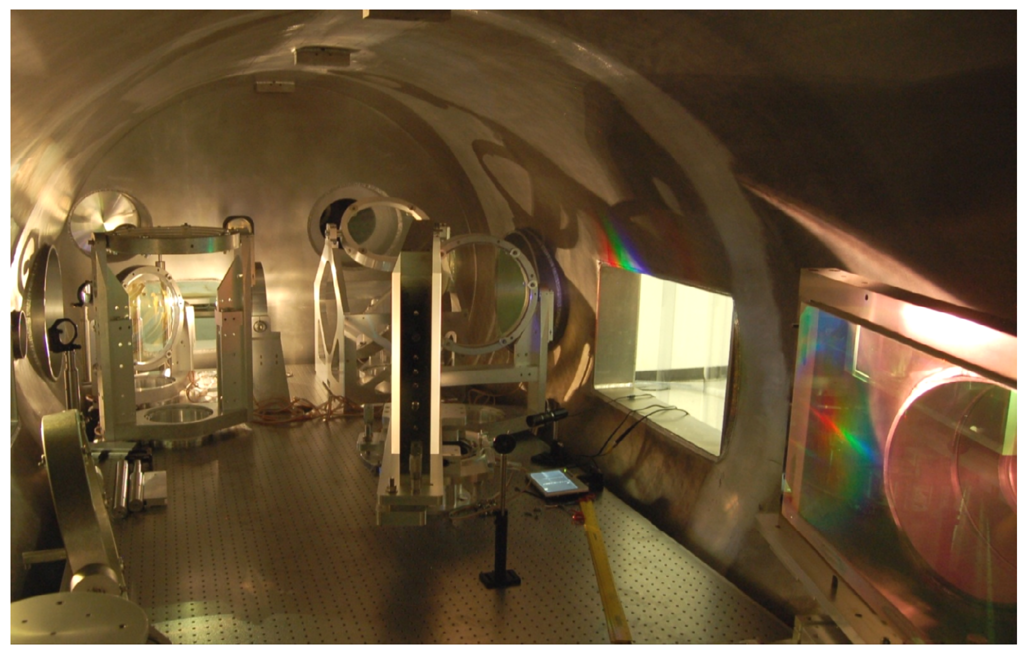




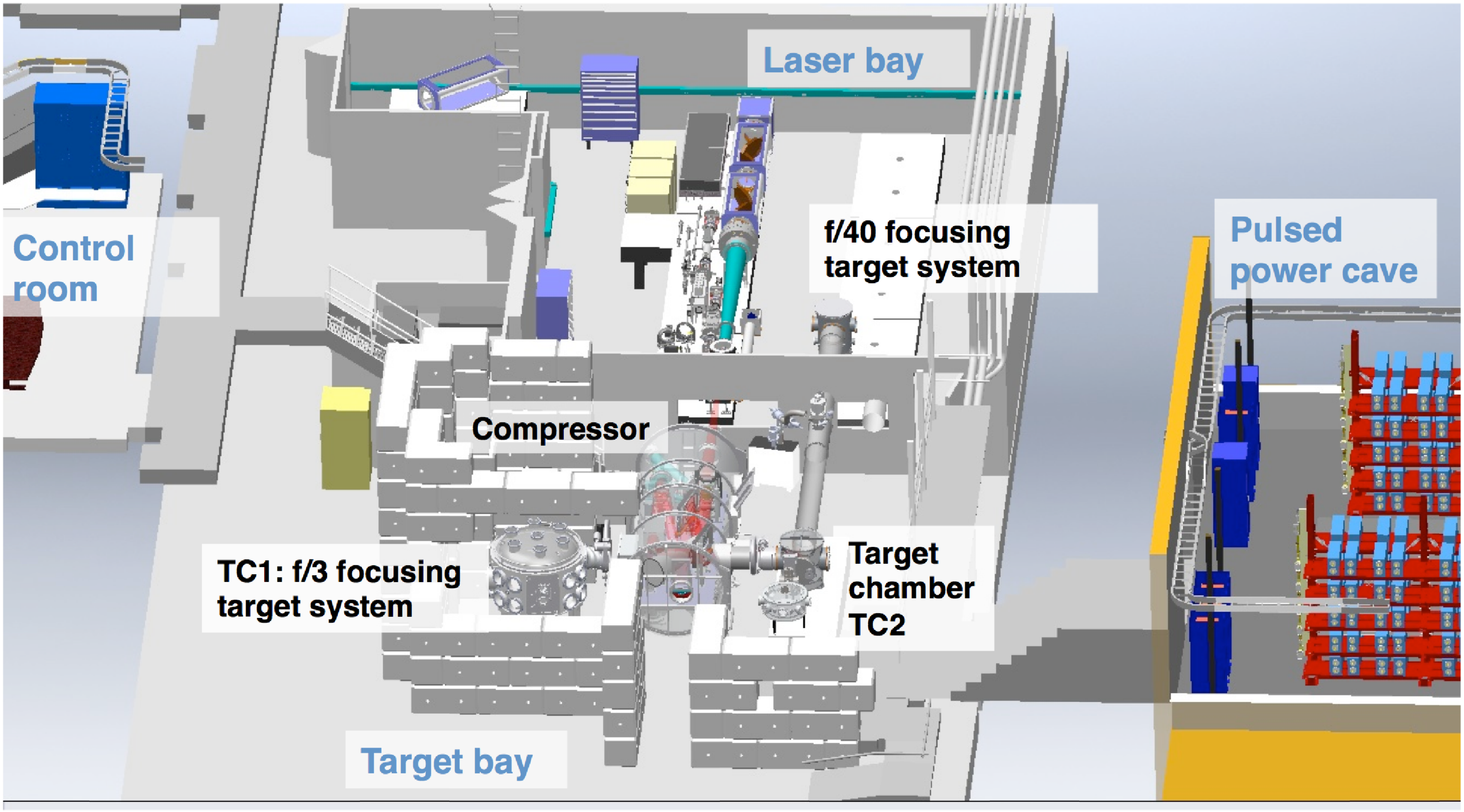


Damage threshold at ³ 100 fs ~ 1 J/cm^2

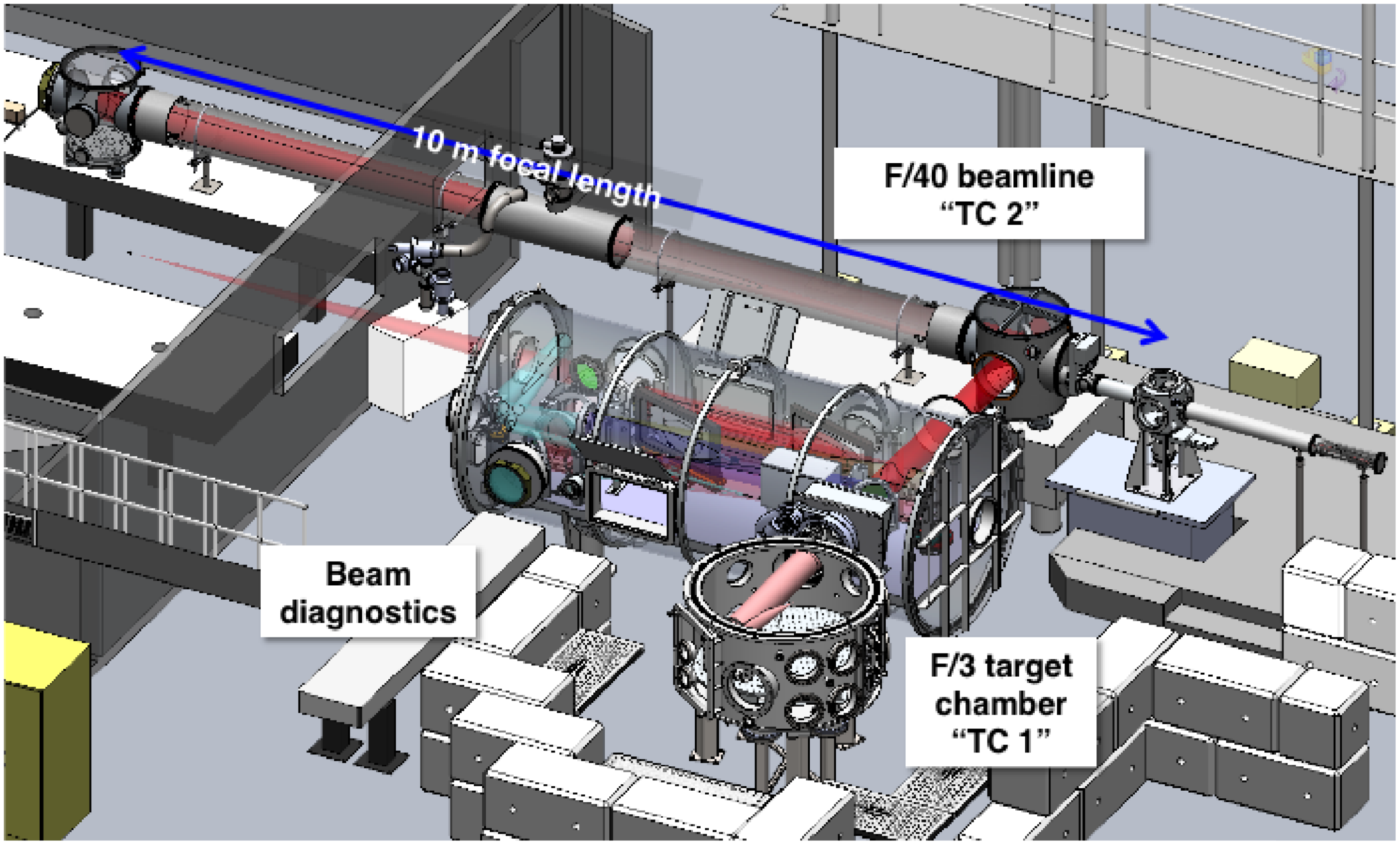
MLD grating compressor throughput: >80%

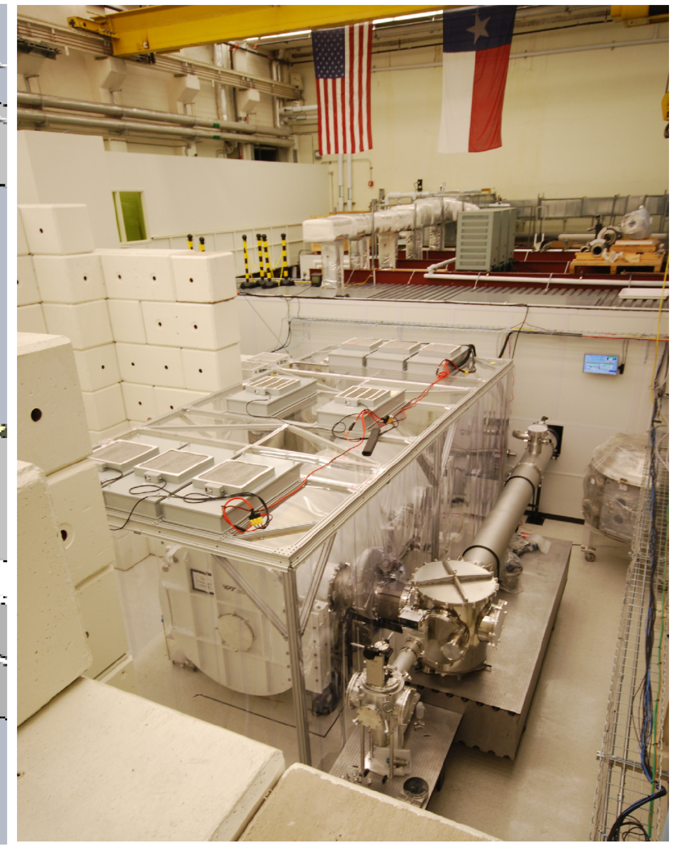


The TPW Laser is housed underground in the UT Austin Robert Lee Moore high bay



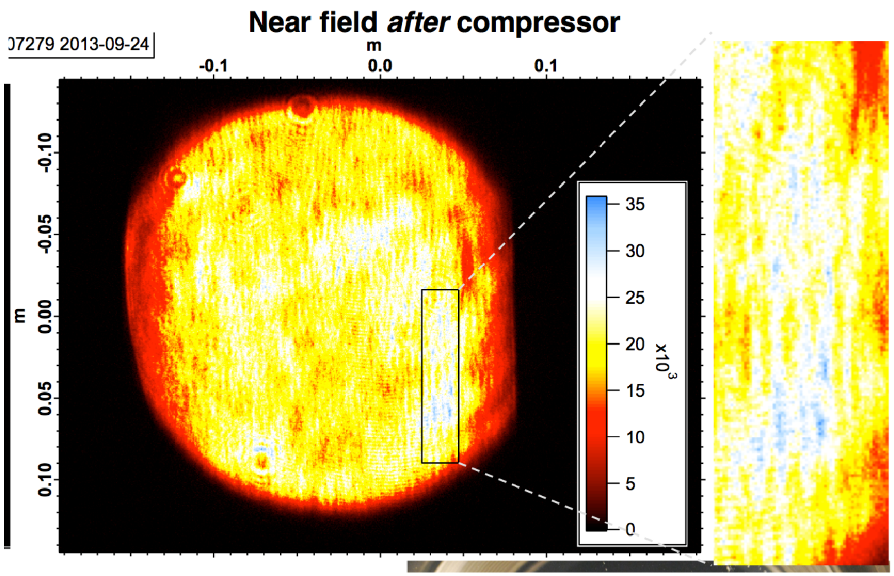
The Texas Petawatt Laser has long and short focal length target areas

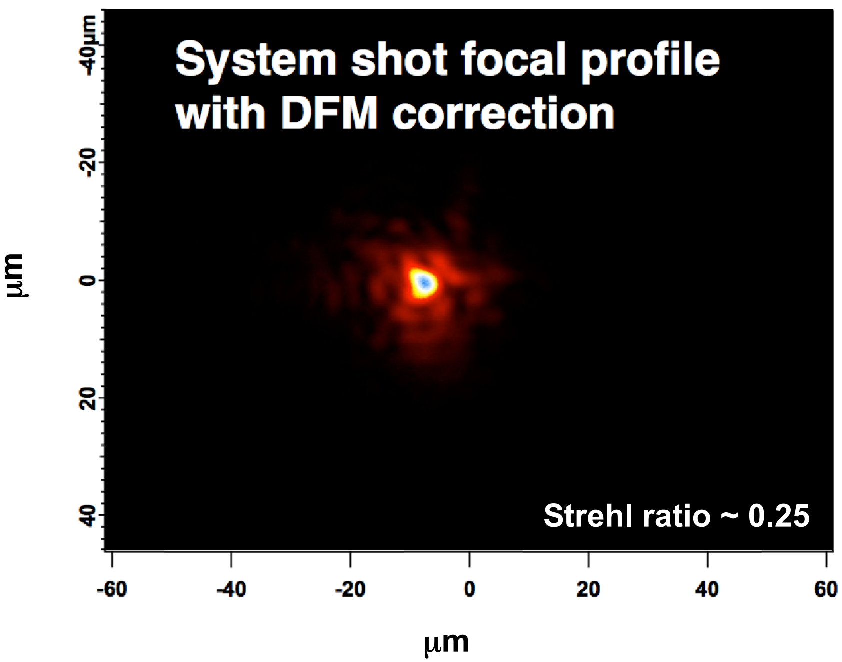


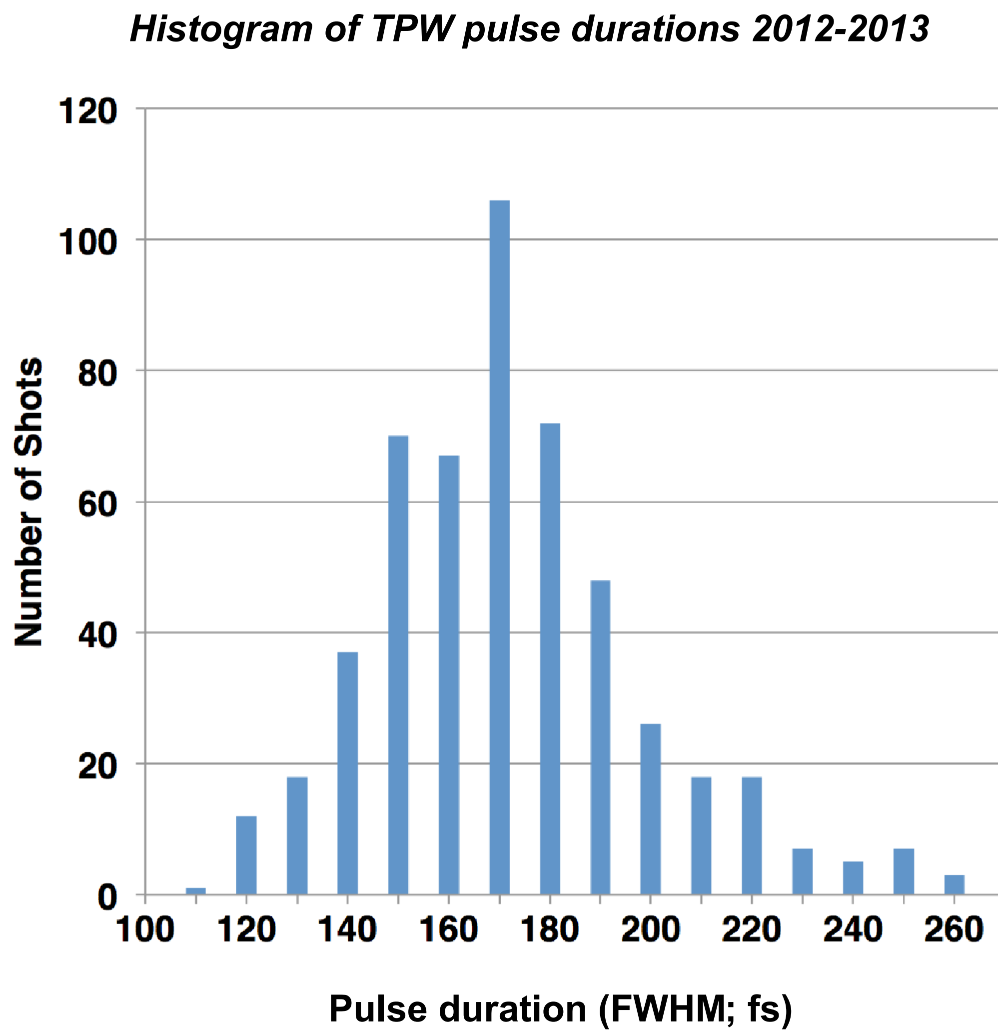


The inclusion of an f/40 focusing geometry gives the Texas Petawatt a unique capability

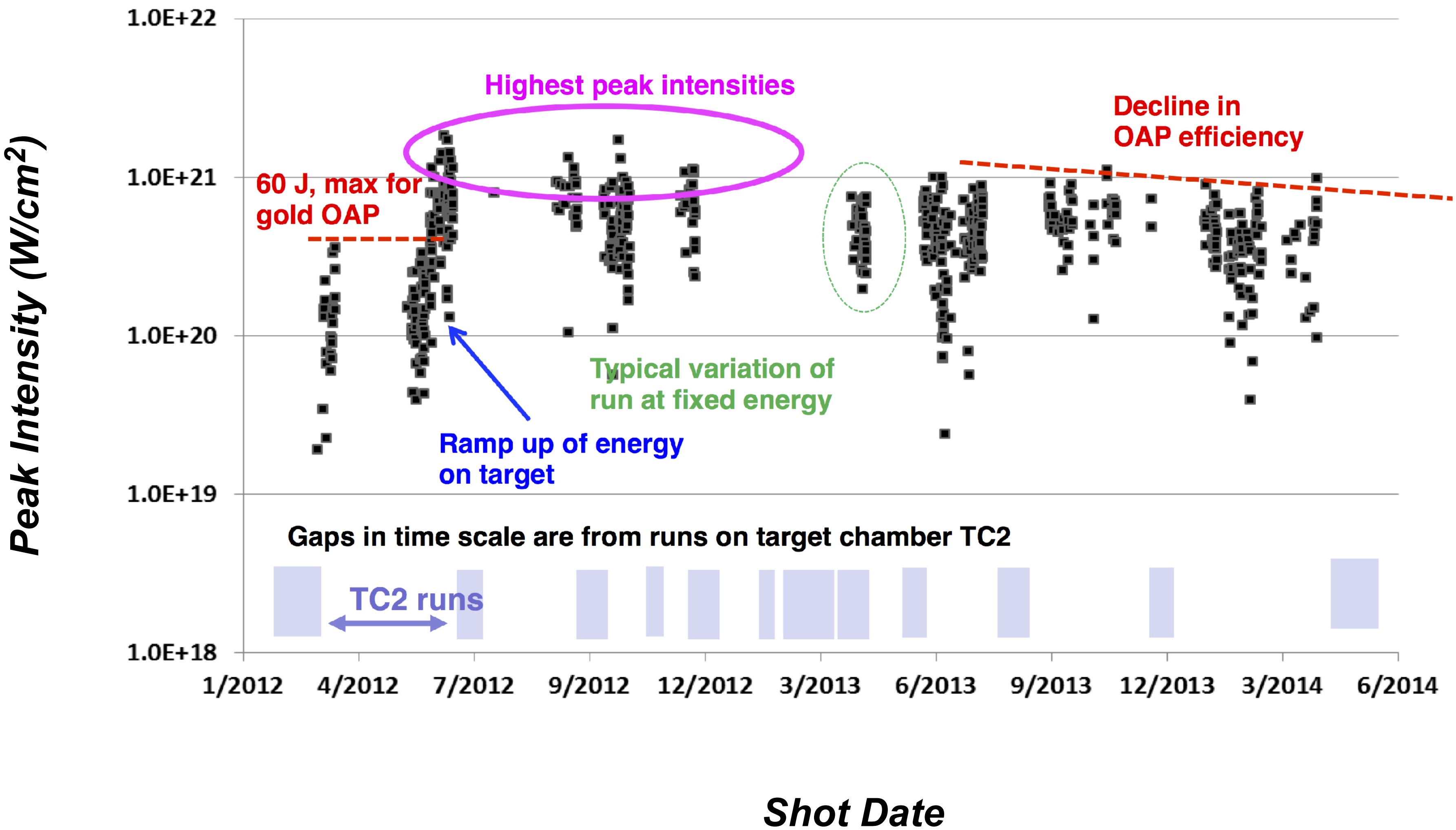
Performance of the Texas Petawatt has been solid over the past two years







The Texas Petawatt currently is limited to peak intensity of ~ 10^{21} W/cm^2



CHEDS has operated a successful user-collaborator program on the Texas Petawatt Laser for the past three years

No other laser system in the world offers the same combination of peak power and pulse energy

170 J, 150 fs

Every potential user (internal and external to UT) competes to be selected for laser time on a rolling three-month basis

Primary considerations are:
• Scientific merit
• Unique suitability for the TPW to achieving experimental goals

Several practical considerations impact our selections
• Cost and availability of required resources (personnel and equipment)
• Potential of damaging the laser system
• Alignment with CHEDS research objectives

CHEDS has operated a successful user-collaborator program on the Texas Petawatt Laser for the past three years

2012 Texas Petawatt Laser Experiments		
Proton Isochoric Heating	Ditmire Group: UT Austin	9-20 Jan 2012
Lithium ion acceleration	The Ohio State University	30 Jan-17 Feb 2012
Advanced TNSA	Los Alamos National Lab	27 Feb-16 Mar 2012
Laser Wakefield Acceleration	Downer Group: UT Austin	26 Mar-4 May 2012
Bright positron sources	Rice, Ohio State, GA, LLNL	14 May-15 Jun 2012
High Harmonic Generation	Keto Group: UT Austin	18-22 Jun 2012
Zr Crystal Imager/Backlighter	The Ohio State University	16-20 Jul 2012
High Harmonic Generation	Keto Group: UT Austin	30 Jul-10 Aug 2012
Proton Isochoric Heating	Ditmire Group: UT Austin	27 Aug-21 Sep 2012
Neutrons from Be Targets	Hegelich/Ditmire: UT Austin	8-26 Oct 2012
Magnetic Vortices	Ditmire Group: UT Austin	5-21 Nov 2012
Microdot Proton Acceleration	Ditmire Group: UT Austin	3-21 Dec 2012

CHEDS has operated a successful user-collaborator program on the Texas Petawatt Laser for the past three years

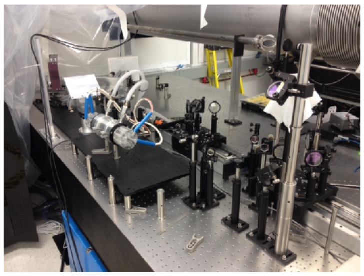
2013-2014 Texas Petawatt Laser Experiments		
Laser Wakefield Acceleration	Downer Group: UT Austin	14 Jan-15 Feb 2013
Ultrathin Target Ion Acceleration	Hegelich Group: UT Austin	11 Mar-5 Apr 2013
Laser Hole Boring	Ditmire Group: UT Austin	15 Apr-3 May 2013
Ultrathin Target Ion Acceleration	Hegelich Group: UT Austin	17 Jun-5 Jul 2013
Bright positron sources	Rice University (E. Liang)	15 Jul-2 Aug 2013
Magnetized Blast Waves	Ditmire Group: UT Austin	19 Aug-6 Sep 2013
Microstructured Snow Targets	Hebrew University-Jerusalem	23 Sep-11 Oct 2013
Prepulse Identification	TPW Staff	22 Oct-15 Nov 2013
Electron Beam Acceleration	UC San Diego (F. Beg)	6-31 Jan 2014
Probing QED Plasma Onset	Hegelich/Ditmire: UT Austin	10 Feb-7 Mar 2014
Mass Limited Targets-Paul Trap	LMU Munich (J. Schreiber)	17 Mar-18 Apr 2014

We have made continual progress toward improving the quality and capability of the TPW

(6/2011) New output sensor package diagnostic layout
- Decouples main beam alignment from diagnostic
- Wavefront sensor DFM control loop can operate for both target chambers

(11/2011) Added1ω/2ω probe pulse with variable delay to TC-1 or TC-2

(2/2012) Changed final focusing mirror from gold to dielectric
- Designed and built 6-axis mount (1/2012)
- Increased energy on target from 60 J to 150 J (2/2012)



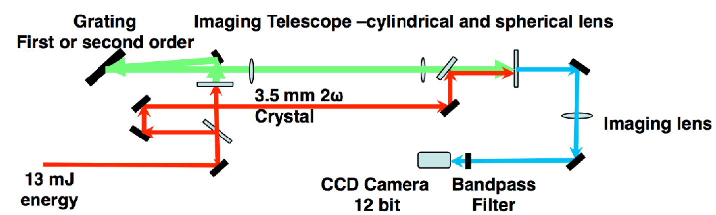
(9/2012) Replaced Pulsed Power Dummy Load Resistors

(2/2013) Replaced 20 kV charging power supply (due to failure)

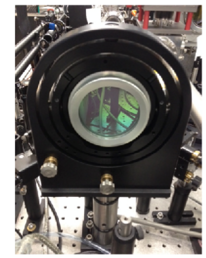
(2/2013) Upgraded Deformable Mirror (DFM) Performance
- Increased aperture in Rod Amplifier to reduce aberrations
- Increased beamsize on DFM to utilize all actuators

(3/2013) Replaced large compressor mirrors

(5/2013) Added Diagnostics
- 3rd order cross-correlator to characterize contrast
- Frog to measure spectral phase to help improve compression



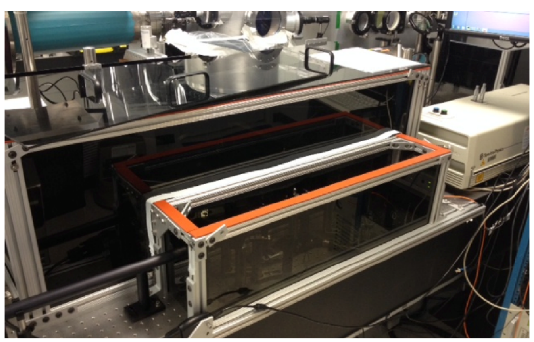
DFM



(3/2012) Added midfield diagnostics

(6/2012) Replaced pulsed power dump rod resistors

(7/2012) Redesigned and built compact stretcher
- Compact design reduces air currents and improves stability
- Modular design allows for future pulse contrast upgrade

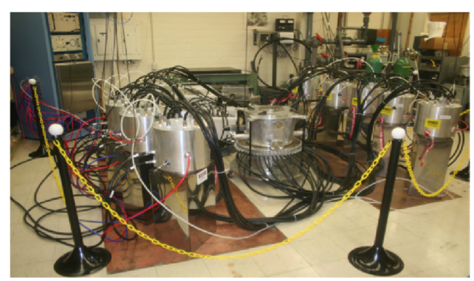


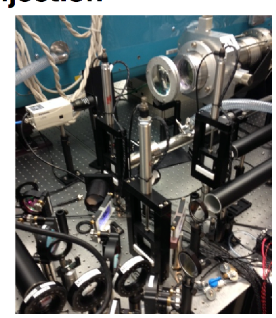
(6/2013) Added 3ω probe capability

(8/2013) Installed pneumatic controls of filters, irises, beam blocks, and energy meters
- Reduce operator error
- Better support User from control room

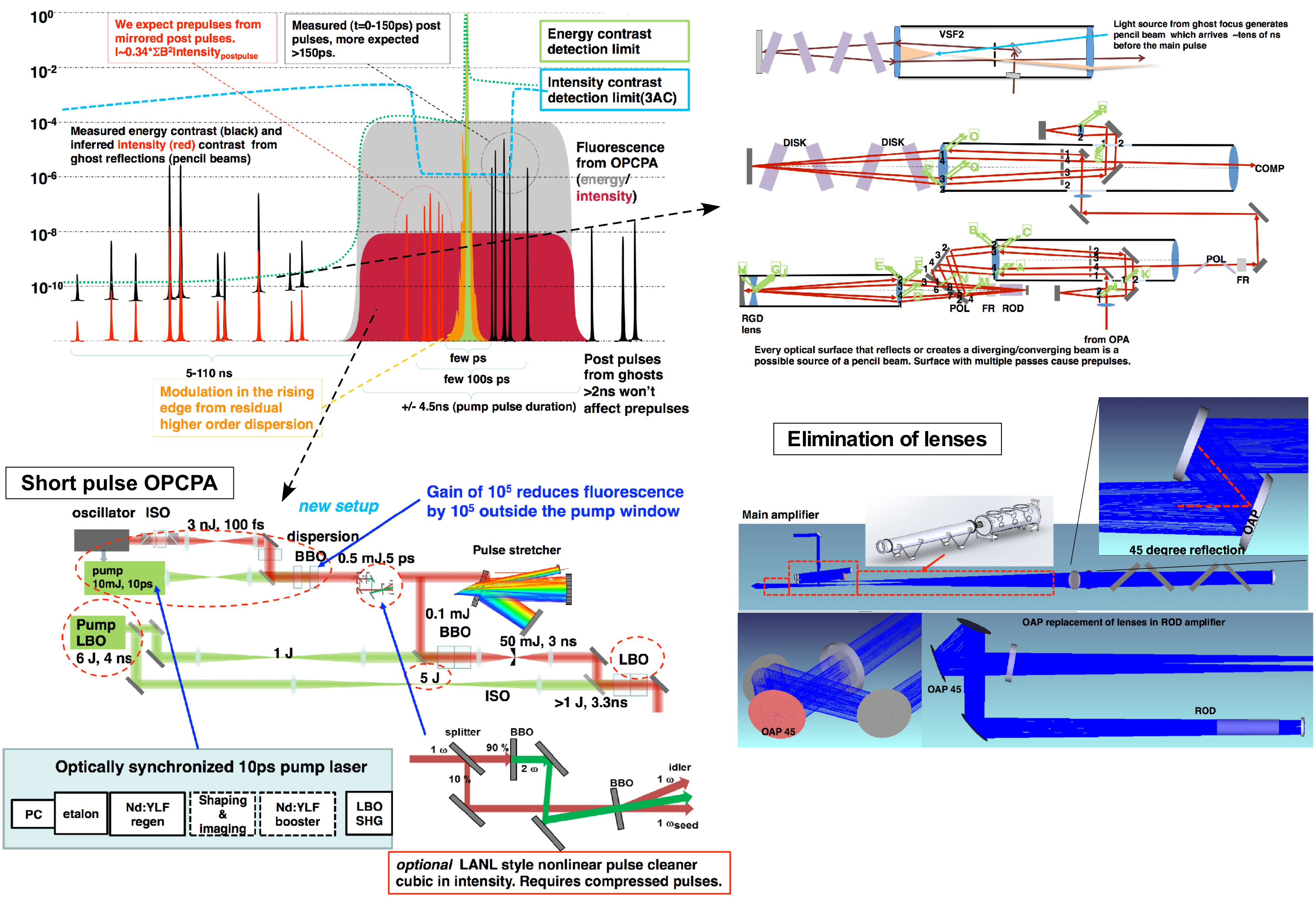
(8/2013) Gained a magnetized HED Physics capability with the MegaGauss system

(9/2013) Integrated remote CW alignment injection





We have a major upgrade funded by DARPA planned in 2014 to improve temporal contrast



UT EH&S governs laser safety and is responsible for State regulation compliance

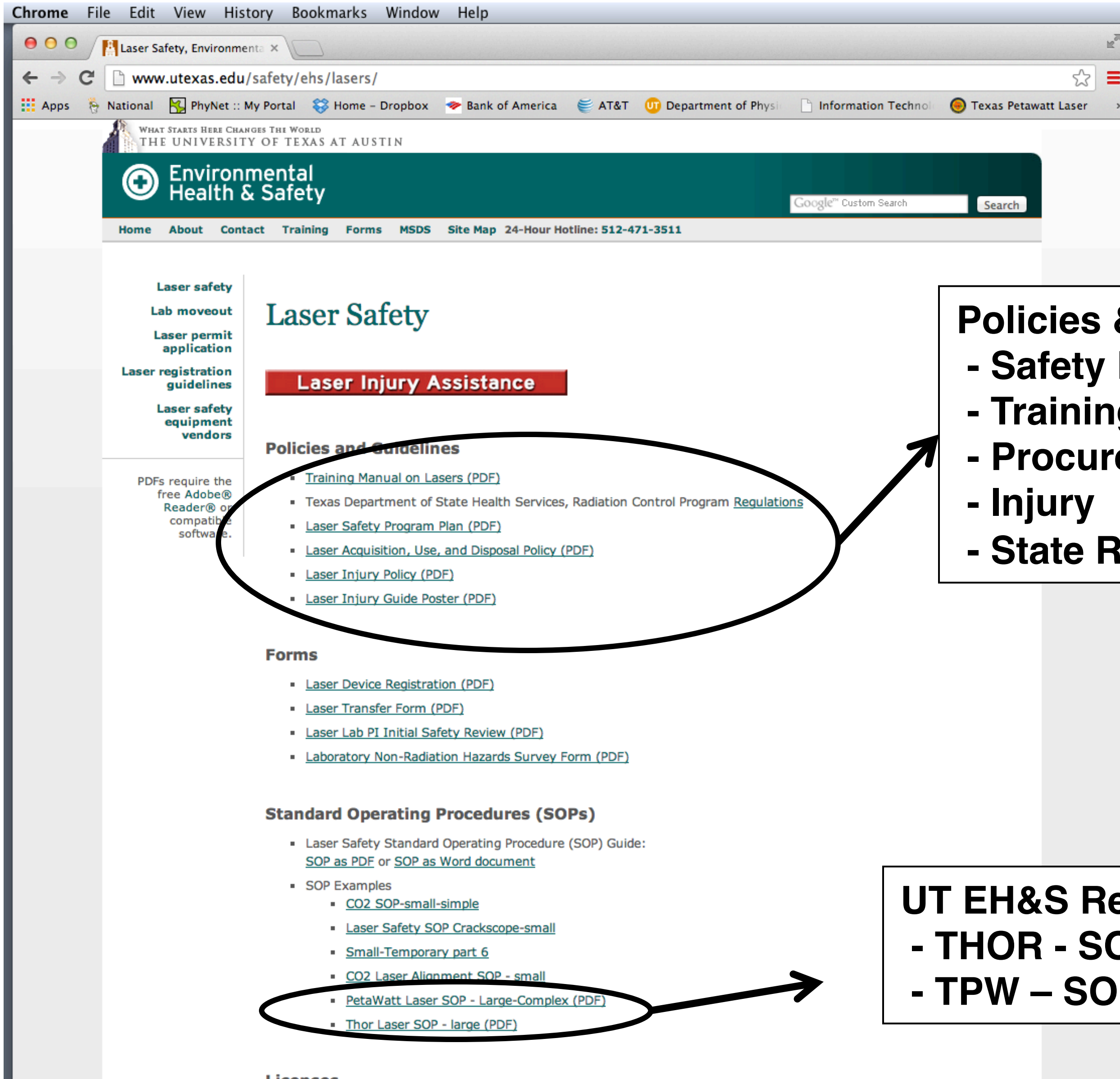
Environmental Health & Safety

THE UNIVERSITY OF TEXAS AT AUSTIN

- The state of Texas regulates lasers and laser safety
- Texas is moving from ANSI 136.7 to the ISO equivalent
- UT EH&S is in the approval loop for all laser (and component) procurements
- There are 400 class IIIb and IV lasers on campus (2 LSO's)
- Every laser is registered with EH&S
- EH&S performs a hazard analysis and requires an SOP for operation
- EH&S has a registered architect on staff to help with new lab or renovation designs

Todd Ditmire chairs the University Laser Safety Committee.
This committee gives guidance to the UT ES&H office on laser safety procedures and interface with University faculty

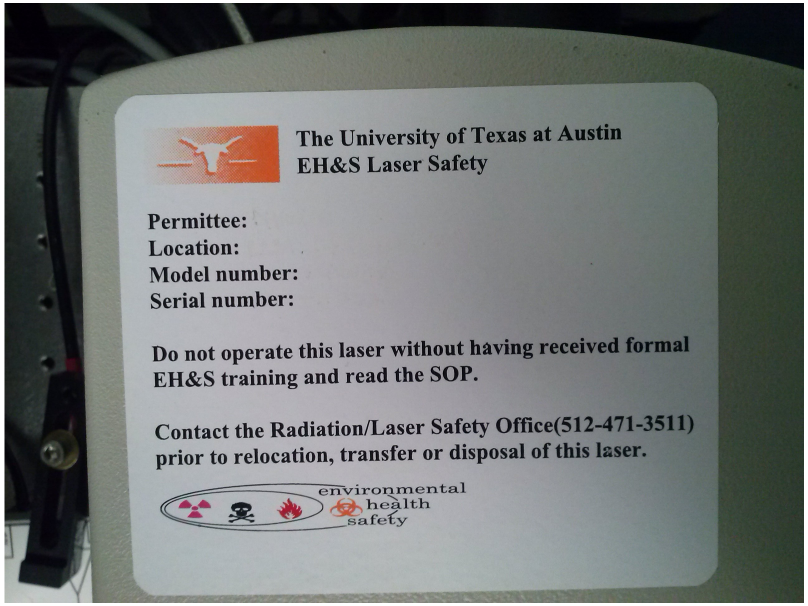
UT EH&S offers easy access to policies and resources related to Laser and Radiation Safety



Policies & Procedures are defined for:
- Safety Program
- Training Manual
- Procurements
- Injury
- State Regulations

UT EH&S References:
- THOR - SOP
- TPW – SOP

EH&S office maintains very active communication with CHEDS technical staff

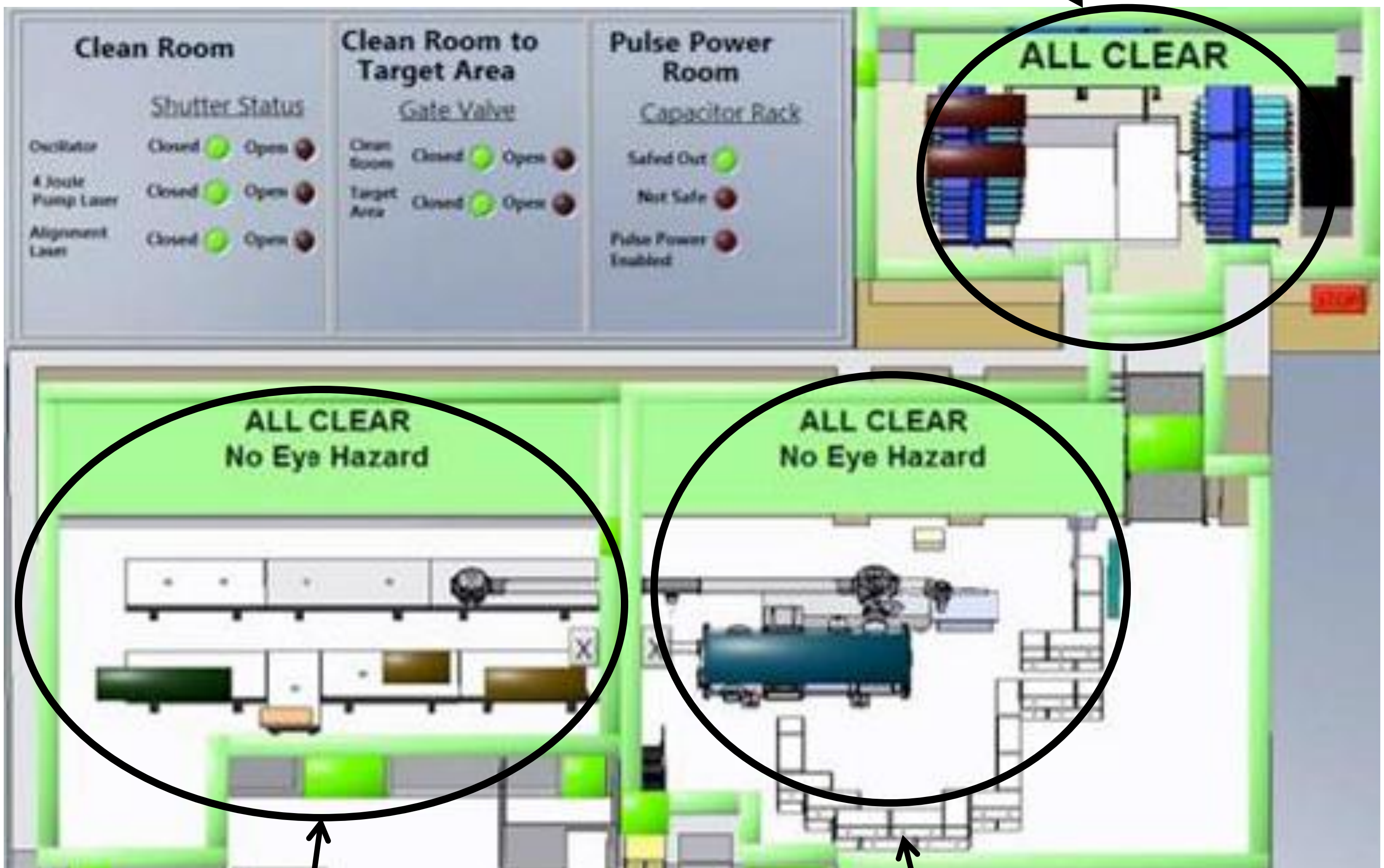


UT EH&S Registration Sticker

- Area radiation monitors are measured monthly and reported to EH&S
- The facility is audited twice a year and training compliance is reported
- An activation rate threshold initiates a call to EH&S
- EH&S visits when new radiation sources are presented or lasers procured
- CHEDS staff communicate on roughly a monthly basis with EH&S staff members (e.g. Scott Pennington)

The Texas Petawatt Laser is divided into 3 hazard zones, each requiring specific training for access

Pulsed Power (Cave)



Laser Bay

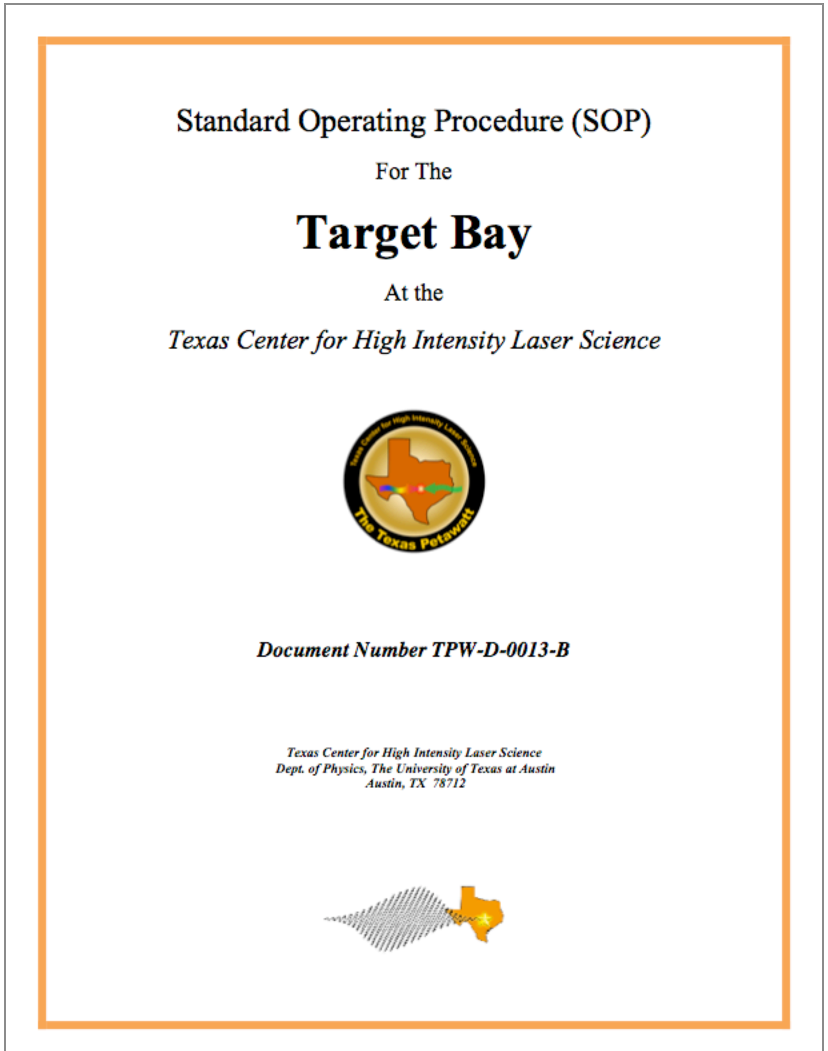
Target Area

Central to our operational safety is training, communication and controlled access

- **All Staff and Users must complete the following UT Safety Training:**
  - OH 101 - Hazard Communication
  - OH 201 - Laboratory Safety
  - OH 304 - Laser Safety
  - OH 102 - Site-Specific Hazard Communication
  - OH 202 – Hazardous Waste Management

- **TPW Safety Training Documents:**
  - Laser Bay Operational Safety Procedure (OSP) - TPW-D-0011-A
  - Qualified Laser Operator Operational Safety Procedures - TPW-D-0014-A
  - Delivering Light into the Target Area & Taking System Shots - TPW-D-0016-A
  - Target Area Operational Safety Procedure - TPW-D-0013-B
  - Pulsed Power System Operational Safety Procedure - TPW-D-0012-B
  - Pulsed Power Safe Out Procedure - TPW-D-0015-B

A Standard Operating Procedure (SOP) governs access to the target bay and establishes safety protocol



Standard Operating Procedure (SOP)

For The

Target Bay

At the

Texas Center for High Intensity Laser Science

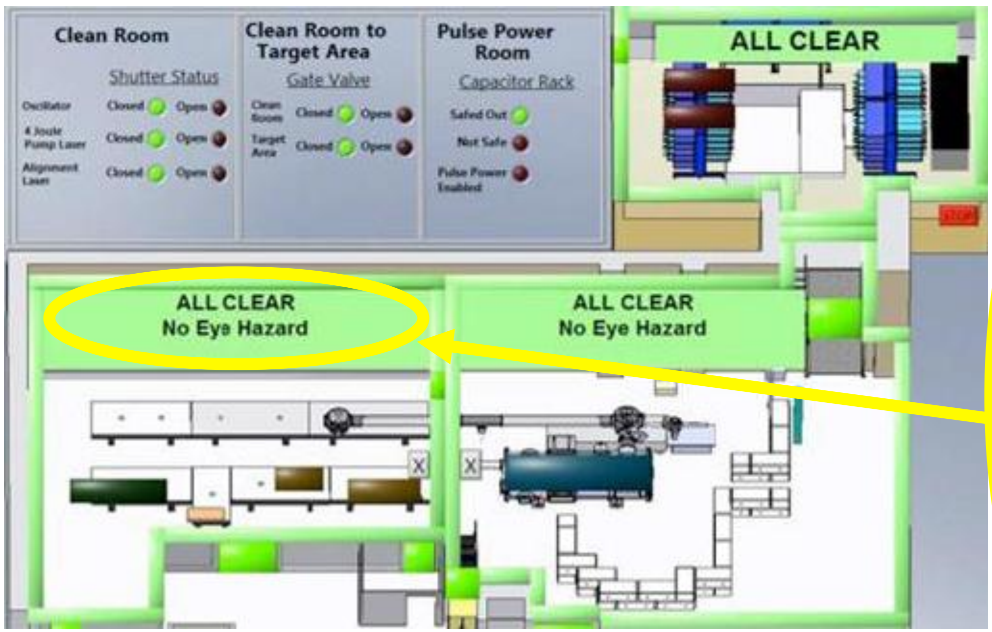
Document Number TPW-D-0013-B

Texas Center for High Intensity Laser Science
Dept. of Physics, The University of Texas at Austin
Austin, TX 78712

- **Clearly describes target bay operations**
  - **Boundaries and regions**
  - **Responsible individuals and operators**
  - **Hazard communication methods**
  - **Different operations modes**

- **Required for unsupervised access to target bay during operation:**
  - **Signature sheet + update confirmation**
  - **Certification of required classes**
  - **Walk-through tour of lab**
  - **Passing a brief oral quiz on safe operating procedures**

Interlock Status Panel communicates 5 different modes of laser operations



ALL CLEAR

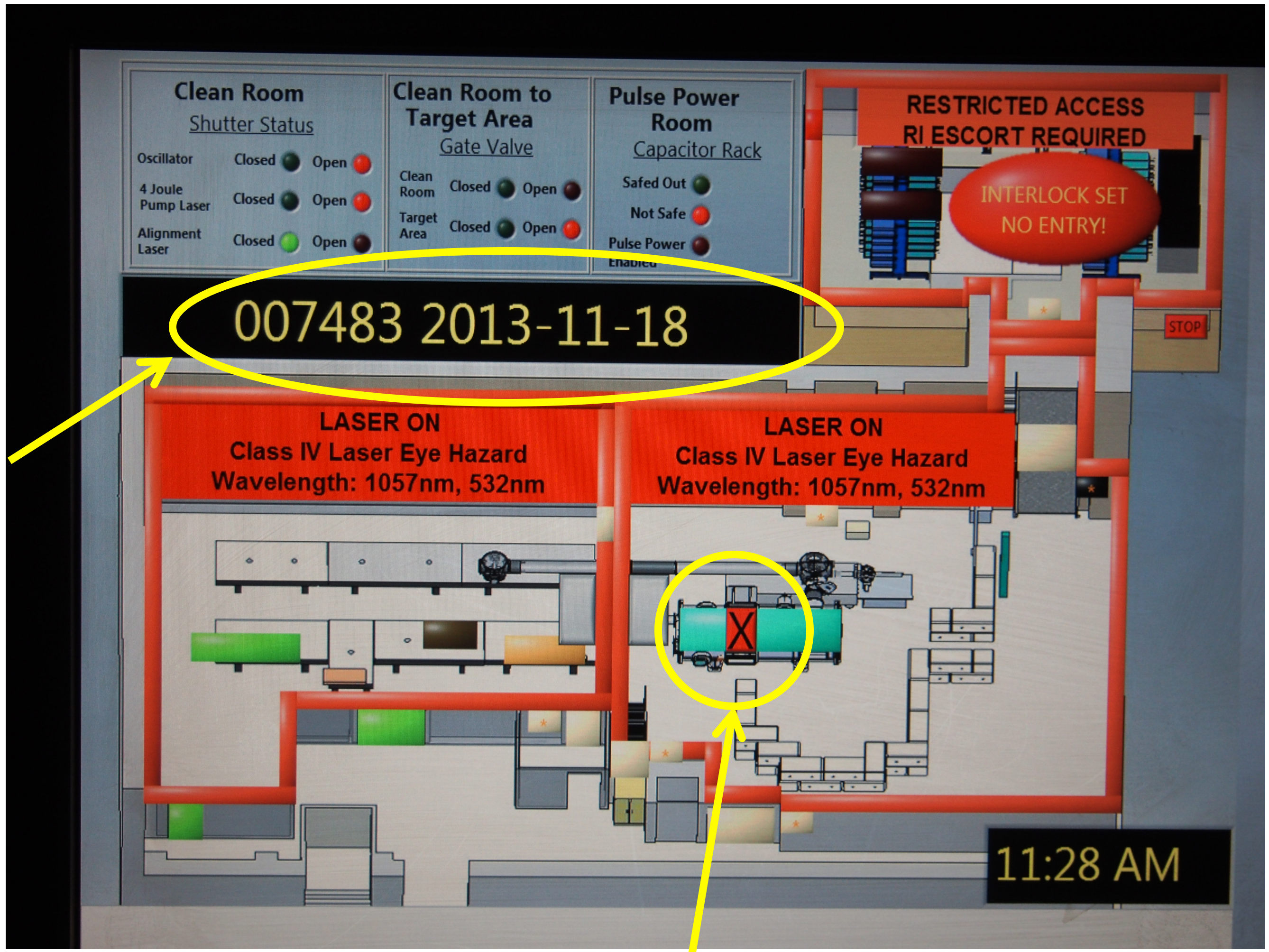
WARM UP

LASER ON
Class IV Laser Eye Hazard
Wavelength: 1057nm, 532nm

ROD SHOT
Class IV Laser Eye Hazard
Wavelength: 1057nm, 532nm

SYSTEM SHOT
Class IV Laser Eye Hazard
Wavelength: 1057nm, 532nm

Interlock Status Panel also communicates technical information for the User and Operators

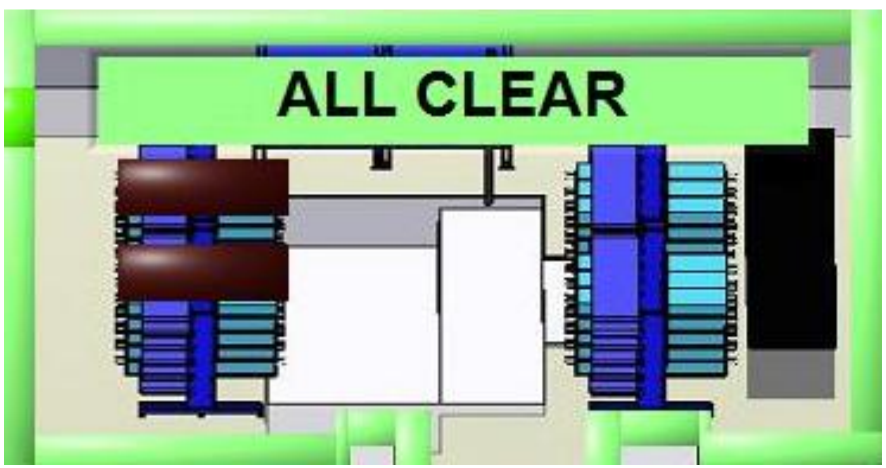


Upcoming Shot Number w/ Date Stamp

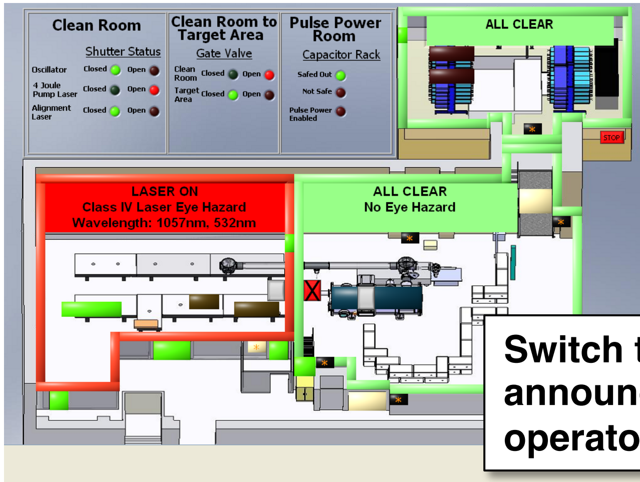
Red "X" shows location where the beam terminates

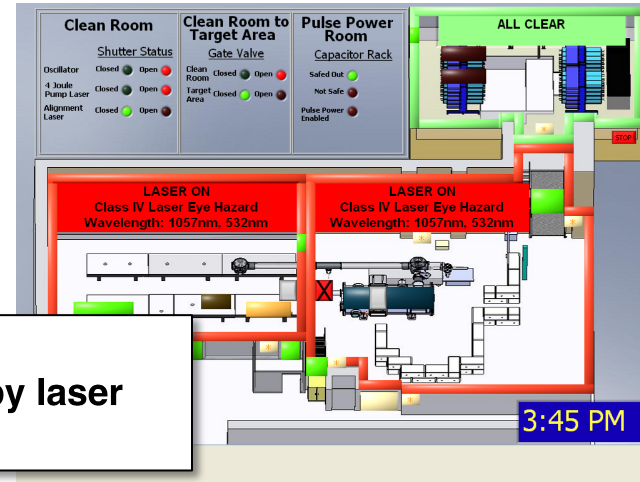
Access control restrictions and multiple operational modes aid in mitigating pulsed power hazards

- Pulsed Power Operational Modes
  - All Clear (Safe)
  - Restricted Access
  - No Entry (Energized)

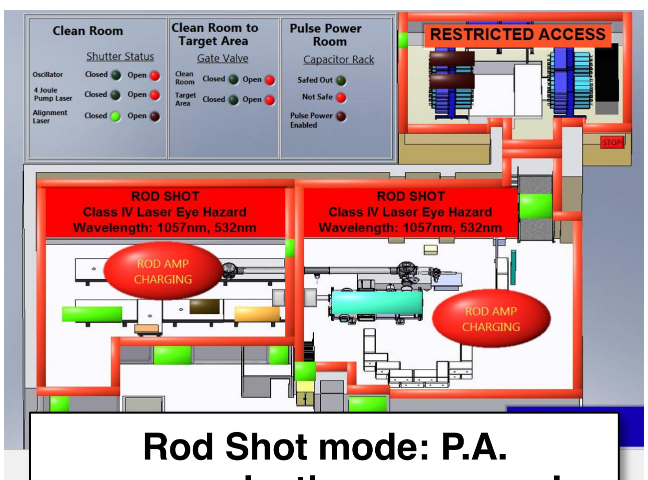


With no direct line of sight from laser bay to target bay, communications are crucial when changing modes

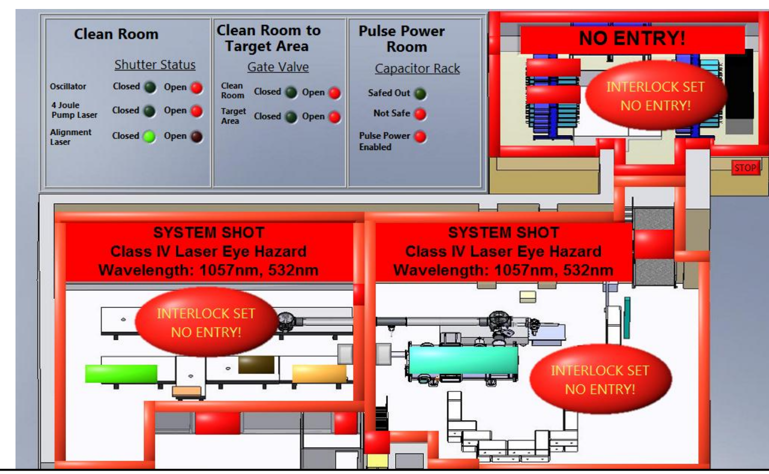




Switch to Laser On: P.A. announcement, sweep by laser operator



Rod Shot mode: P.A. communication, personnel make contact with operator



System Shot Mode: P.A. announcement, complete evacuation procedure, door interlocks

We maintain lists to track each researcher's PPE goggle type and condition

THOR Laser Safety Inventory, 12th floor, CHEDS

Monday August 26, 2013

Goggle Number (label)	Mode	Type	Comments	Rate
02062 Dark	Operation	G	Very Slight wear	Good
Aaron	Operation	G	Very Slight wear	Good
Ahmed	Operation	NG		New
Alignment1	OSC alignment	G		New
Alignment2	OSC alignment	G		New
Alignment3	OSC alignment	G		New
Alignment4	OSC alignment	G		New
Andrew	Operation	NG	Very Slight wear	Good
Hernan	Operation	NG		Good
In Tai	Operation	NG	Very Slight wear	Good
Keto	Operation	NG		Good
Matt	Operation	NG		Good
Visitor 2	Operation	NG		Good
Visitor 1	Operation	G	Very Slight wear	Good
Sandi	Operation	NG		New
Visitor 5	Operation	NG		Good
Visitor 8	Operation	G		New
Woosuk	Operation	G	Very Slight wear	Good
Visitor 4	Operation	NG	Very Slight wear	Good

Goggles refreshed at semi-annual intervals

GHOST Laser Safety Inventory, 12th floor, CHEDS

Monday August 26, 2013

Goggle Number (label)	Mode	Type	Comments	Rate
Alignment	Alignment	NG		New
Alignment	Alignment	NG		New
Clay	Operation	G		New
Gilliss	Operation	NG	Very Slight wear	Good
Ishay	Operation	NG		New
Joel	Operation	NG		New
Kristina	Operation	NG		New
Nathan	Operation	NG	Very Slight wear	Good
Sean	Operation	G		New
Rebecca	Operation	G		New
Alex	Operation	NG		New
Eddie	Operation	NG		New
Chunhua	Operation	NG		New
Erhard	Operation	NG		New
Todd	Operation	NG		New
Visitor 2	Operation	NG		New
Visitor 3	Operation	G		Good
Visitor 6	Operation	G		New
Visitor 11	Operation	NG		Good

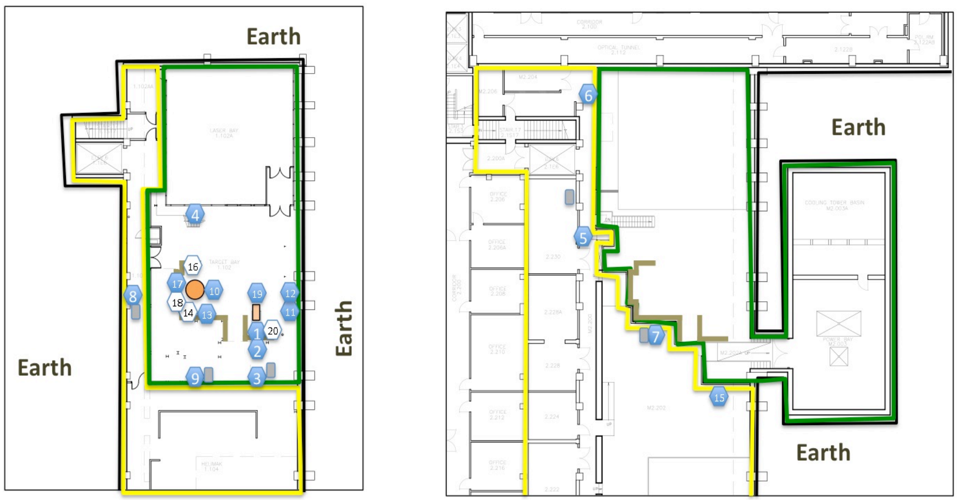
We work closely with environmental health and safety (EH&S) to ensure radiological safety

Landauer area monitor placement map

10′

First floor

Second floor



Passive monitors (Landauer)

Active monitors

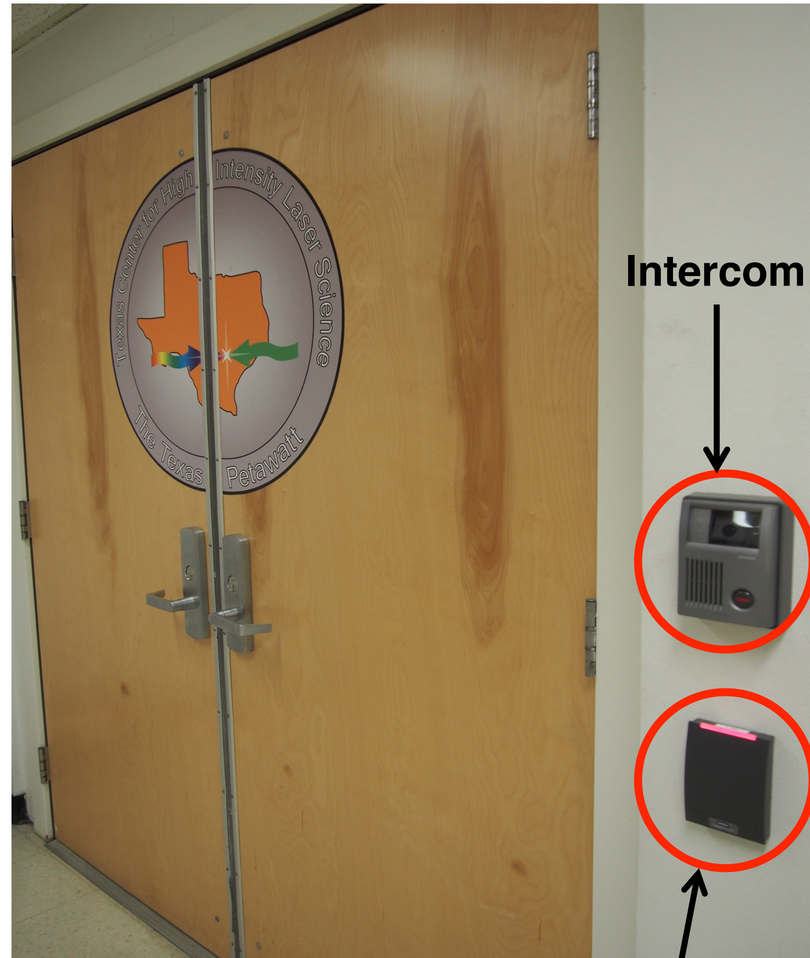
Passive monitors at elevated height (line of sight to working area from TCC)

2401-P survey meter to check for activated materials

- **EH&S and TPW staff monitor 20 dosimeters with Landauer, changed monthly**
- **TPW staff and graduate students trained in radiological safety (specialized course)**
- **Monitors distributed inside and outside of radiation walls**
- **2012 dosage at "hottest" point near chamber: 14 rem in 5 runs**
- ***1 mrem/hr activity threshold for contacting EH&S***

Access to the Facility, Laser Bay and Target Area is now controlled with key cards

- UT ID cards are used to gain access
- The TPW Safety Officer has administrative rights
- Access is granted to Users, Staff and Students that have completed training
- An intercom system allows for one time access which is controlled by the laser operator
- System was paid for by UT



Crash buttons in the Control Room and Cave safely discharge the capacitors into dump resistors

Pulsed Power

Control Room

- **Hard wired to Pulsed Power – no computers or software involved in dumping high voltage**
- **Control Room and Pulsed Power locations**
- **Breaking door interlocks also dumps pulse power high voltage**